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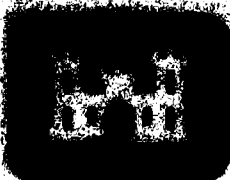
Hydraulic Model Investigation

by

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October 1982

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Los Esteros Spillway
Pecos River
Spillways

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Tests to investigate the hydraulic performance of the Los Esteros Spillway and discharge channel were conducted using a 1:80-scale model. Emphasis was placed on the development of a design that would pass flows as high as 430,000 cfs without subjecting the downstream dam embankment to excessive surges and current velocities.

Approach flows and flows passing over the crest were satisfactory for all anticipated discharges.

(Continued)

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20. ABSTRACT (Continued)

Discharges above 225,000 cfs induced adverse currents, surges, and stone failure on the downstream face of the dam. Portions of the ravine or discharge channel were excavated and the amount of turbulence, surges, and currents along the downstream face of the dam was reduced to an acceptable level. However, the cost of prototype excavations was considered excessive.

Properly designed flow deflectors in the ravine were effective in reducing adverse hydraulic conditions at the downstream dam embankment. The deflectors shifted flow away from the dam and down the Pecos River. A fixed deflector (concrete wall) was effective but considered undesirable for economic reasons.

The design adopted by the Albuquerque District consisted of a rock flow deflector in the ravine and a rock fill on the dam embankment constructed of material obtained from the spillway excavation. Although the model indicated that portions of the sacrificial type rock fill would be displaced when subjected to flows above 225,000 cfs, the safety of the dam was not endangered by discharges as high as the design flow of 430,000 cfs.
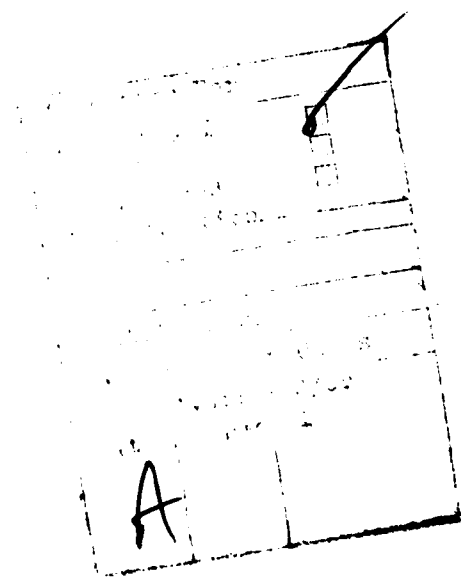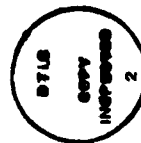
PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers, U. S. Army, 20 February 1979, at the request of the U. S. Army Engineer District, Albuquerque.

The study was conducted during the period February 1979 to April 1980 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, and under the general supervision of Messrs. J. L. Grace, Jr., Chief of the Hydraulic Structures Division, and N. R. Oswalt, Chief of the Spillways and Channels Branch. Project Engineer for the model study was Mr. B. P. Fletcher, assisted by Mr. B. Perkins. This report was prepared by Mr. Fletcher.

During the course of the investigation, Messrs. Sam Powell and Wayne McIntosh of the Office, Chief of Engineers; Dick Berryhill, Chester Berryhill, Sam Aiken, Bob James, Jim Harrison, and Tasso Schmidgall of the U. S. Army Engineer Division, Southwestern; and COL Bernard J. Roth, Messrs. Jasper Coombs, Elias Quintana, Kim Zahm, Wayne Dillard, and John Cunico of the Albuquerque District visited WES to discuss the program and results of tests, observe the model, and correlate test results with overall design features of the prototype.

Commanders and Directors of WES during the conduct of the study and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

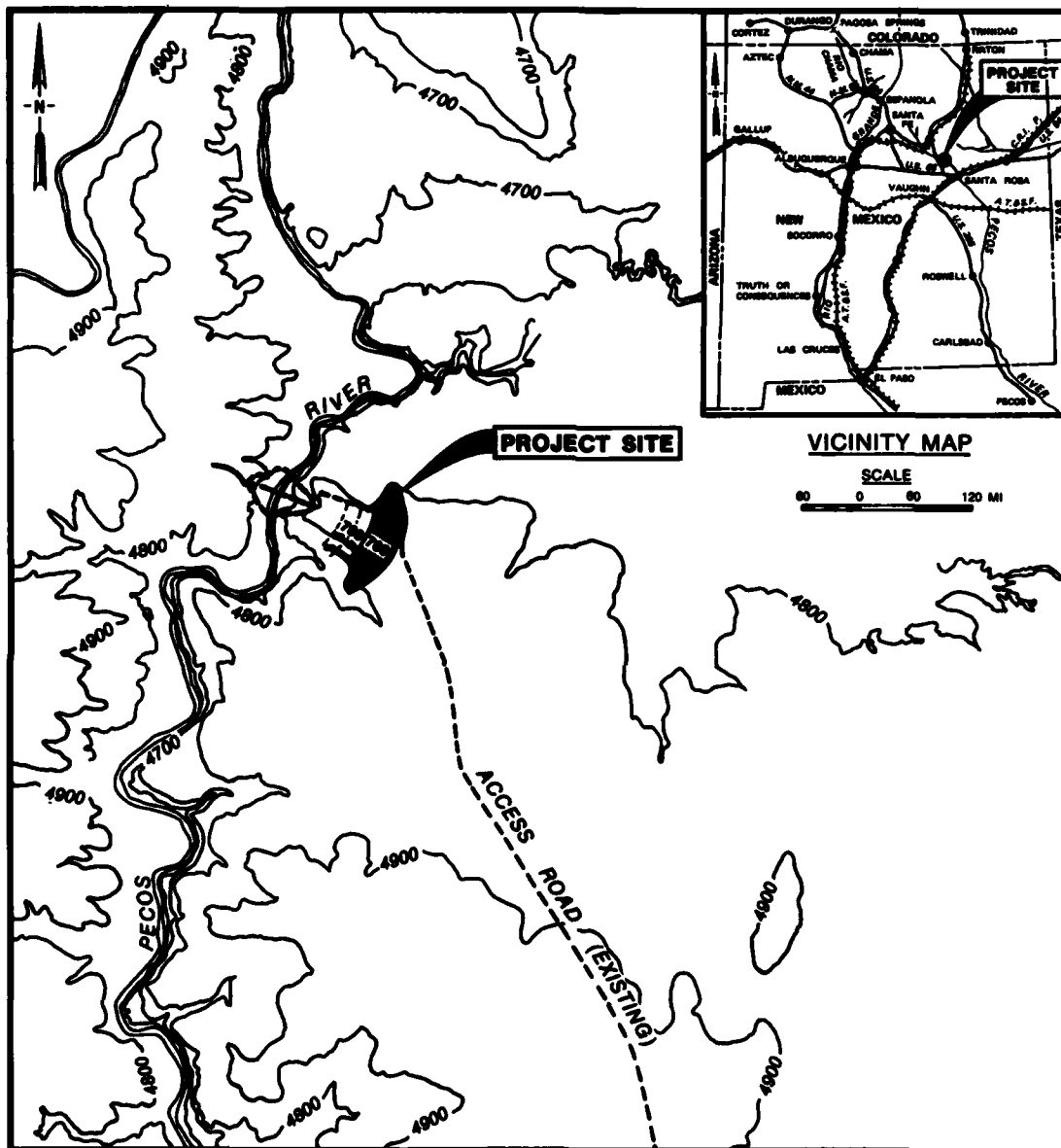| Multiply	By	To Obtain
acre-feet	1233.482	cubic metres
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres

Figure 1.   Location map

LOS ESTEROS SPILLWAY, PECOS RIVER, NEW MEXICO

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The Los Esteros Spillway is located in Guadalupe County, New Mexico, about 7 miles* north of the city of Santa Rosa about river mile 766 on the Pecos River (Figure 1). The project will provide for 449,000 acre-feet of storage, of which 167,000 will be allotted to flood control, 200,000 to irrigation, and 82,000 to sediment reserve. The embankment will be about 1,900 ft long and 210 ft high (el 4824)** in the maximum section. A 1,400-ft-wide spillway will be located to the left of the dam abutment. Flood control and irrigation releases will be made by means of the gated 10-ft-diam conduit through the dam. Irrigation water stored in the project will be used on land in the Carlsbad Irrigation District. Access to the project will be by an access road from Santa Rosa.

2. The existing 700-ft-wide spillway is designed to pass a discharge of 175,000 cfs; however, recent floods and estimates of the maximum probable flood necessitated widening the spillway to 1,400 ft to provide a capability of passing 430,000 cfs with a 24-ft head and a pool elevation of 4821.

3. The uncontrolled spillway located to the left of the dam abutment will consist of a rock-cut trapezoidal channel with 4V-on-1H side slopes (Plate 1). Maximum depth of the cut is about 40 ft, near the crest on the west or right side of the spillway. The curved spillway will be about 1,000 ft long and will slope up (0.002 ft/ft) for about

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  * A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.
 ** All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

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650 ft to the concrete control weir at el 4797 and will then slope
down (0.002 ft/ft) for about 350 ft. The hydraulic control for the
spillway channel will be along the irregular downstream edge of the
channel where the cut intersects natural ground. Spillway discharges
will enter the natural drainage channel or ravine, located immediately
downstream from the spillway, and be conveyed to the Pecos River at a
point about 1,000 ft downstream from the toe of the dam. Sufficient
energy dissipation should occur under initial conditions to induce the
formation of a hydraulic jump in the Pecos River.

4. The reservoir outlet works, Plate 1, is designed to pass a
maximum flow of 6,140 cfs and will consist of an approach channel, up-
stream gate control tower, 10-ft-diam conduit, and flip bucket energy
dissipator. The approach channel is approximately 160 ft long and 30 ft
wide. The control tower is a freestanding structure, 226 ft high above
foundation grade. Flows through the conduit will be controlled by two
5- by 9-ft slide gates. A flip bucket is located at the downstream end
of the 1,128-ft-long conduit.

Purpose of Model Study

5. The model was used to investigate anticipated flow conditions
in the approach and exit areas, and discharge characteristics of the
existing 700-ft-long spillway and enlarged spillways with crest lengths
of 1,100 and 1,400 ft. Model tests were primarily conducted to develop
a practical design for the 1,400-ft-long crest that would permit passage
of anticipated flows as high as 430,000 cfs without severe currents and
wave action along the downstream dam embankment.

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Description

6. The comprehensive model (Figure 2) was constructed to a linear scale ratio of 1:80 and reproduced 1,300 ft of the approach, the dam, the spillway, the ravine, and 4,000 ft of the Pecos River downstream from the dam. The outlet structure was schematically simulated. The spillway was designed to permit evaluation of crest lengths of 700, 1,100, and 1,400 ft. The portions of the model representing the approach, dam, and exit areas were molded of cement mortar to sheet-metal templates and were given a brushed finish; the uncontrolled spillway was constructed of cement mortar with a slick finish.

7. Water used in the operation of the model was supplied by pumps, and discharges were measured with venturi meters. Steel rails set to grade provided reference planes for measuring devices. Water-surface elevations were obtained with point gages; velocities were measured by means of a pitot tube.

Scale Relations

8. The accepted equations of hydraulic similitude, based upon Froudian criteria, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype. The general relations expressed in terms of the model scale or length ratio, L_r, are presented in the following tabulation:

Dimension	Ratio	Scale Relation
Length	L_r	1:80
Area	$A_r = L_r^2$	1:6,400
Velocity	$V_r = L_r^{1/2}$	1:8.9443

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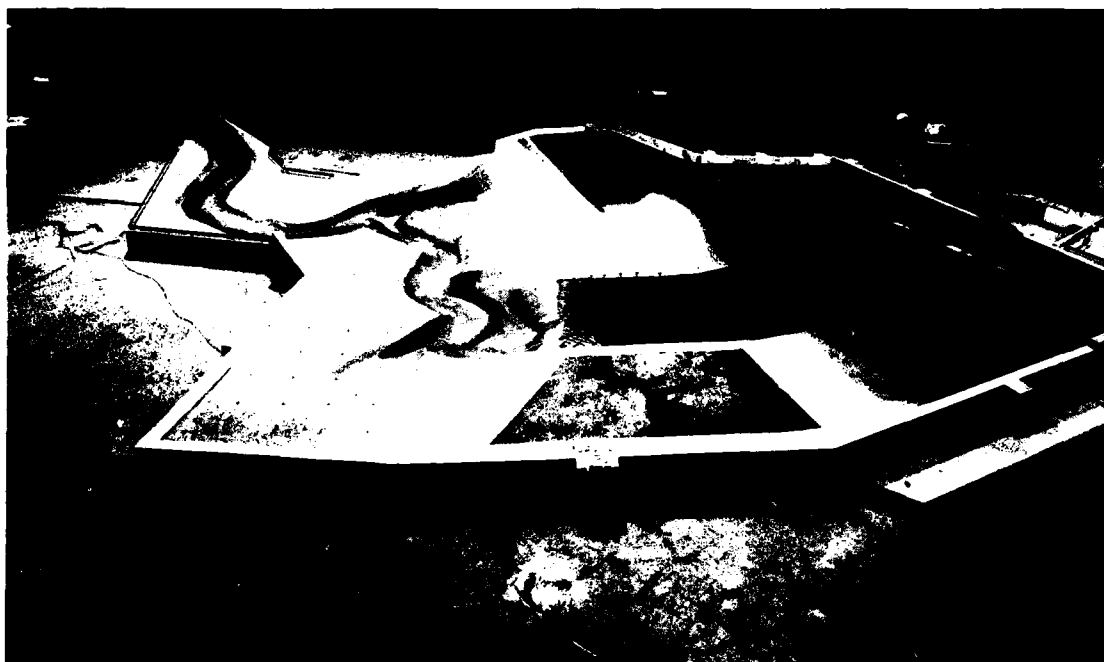
a. Overhead view (700-ft-long spillway)

b. Dam and outlet structure viewed from downstream

Figure 2. The 1:80-scale comprehensive model

Dimension	Ratio	Scale Relation
Discharge	$Q_r = L_r^{5/2}$	1:57,243.52
Time	$T_r = L_r^{1/2}$	1:8.9443
Volume	$V_r = L_r^3$	1:512,000

9. Model measurements of each dimension or variable can be transferred quantitatively to prototype equivalents by means of the preceding scale relations.

PART III: TESTS AND RESULTS

Presentation of Data

10. No attempt has been made to present the model tests and re-
sults in chronological order; instead, as each element of the structures
is considered, all tests conducted thereon are described in detail.

Approach Flows

11. The approach area reproduced in the model (Figure 2) extended
about 1,300 ft upstream. For the three spillway crest lengths (700,
1,100, and 1,400 ft) evaluated, approach flows were satisfactory. Only
minor flow contraction occurred at the spillway abutments.

Spillway Crests

Existing and alternate length crests

12. Existing and alternate length crests of 700 and 1,100 ft de-
signed to pass discharges of 175,000 and 385,000 cfs, respectively, were
investigated. Spillway rating curves and plots of discharge versus
head on the crest for various crest lengths are plotted in Plates 2
and 3. Basic spillway calibration data obtained from the model are
tabulated in Table 1.

13. Maximum flows anticipated for the 700- and 1,100-ft-long
crests are shown in Figure 3. Crest flow characteristics were satis-
factory for both lengths of spillway and their respective anticipated
discharges. Downstream from the crest, discharges greater than
225,000 cfs generated excessive wave heights and currents near the down-
stream face of the dam. Wave wash, tailwater elevation, and current
velocities measured near the downstream face of the dam with both the
700- and 1,100-ft-long crests and various discharges are included in
Plates 4, 5, and 6.

a. 700-ft-long crest, discharge 175,000 cfs
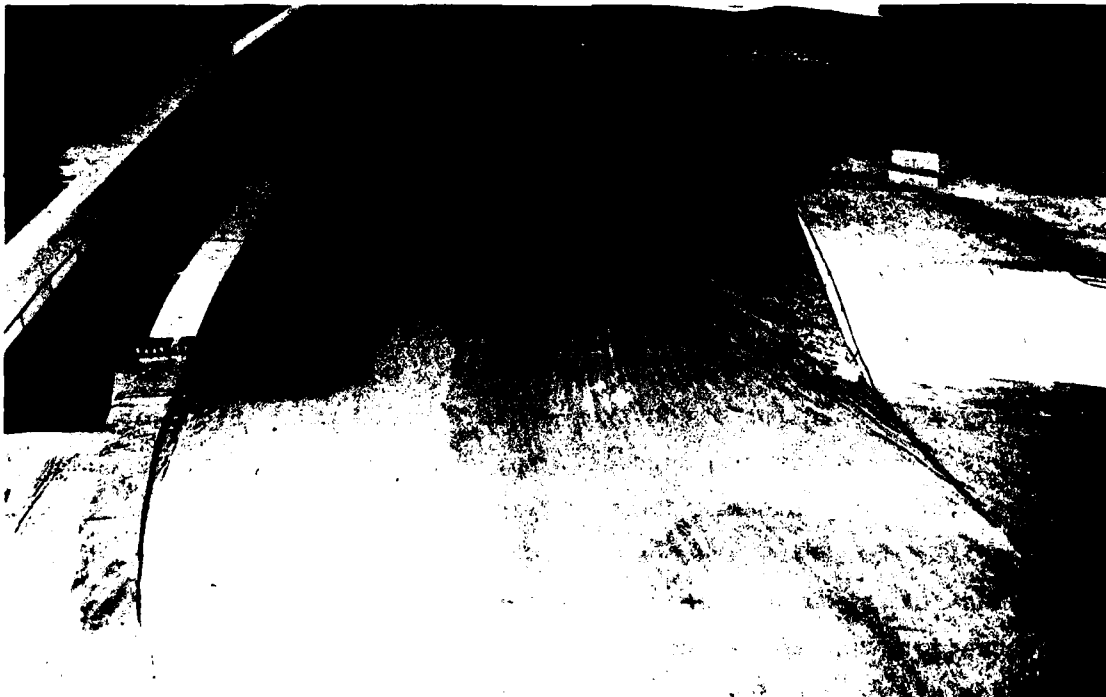
b. 1,100-ft-long crest, discharge 385,000 cfs

Figure 3. Alternate length crests

1,400-ft-long crest (adopted)

14. Revised estimates of the maximum probable flood necessitated investigating a 1,400-ft-long crest designed to pass a maximum flow of 430,000 cfs. Computed and model spillway rating curves are shown in Plate 2. A plot of discharge versus head on the crest is shown in Plate 3. Basic spillway calibration data obtained from the model are presented in Table 1. Various flow conditions observed in the spillway are shown in Photo 1. Approach flows to the spillway were satisfactory for all anticipated flows. Only minor flow contractions occurred at the spillway abutments.

Exiting Flows

15. The discharge channel was simulated for a distance of 4,000 ft downstream from the dam and simulated water-surface profiles computed in the Pecos River for all anticipated flows. For a given discharge, regardless of the length of crest, similar hydraulic characteristics were observed at the confluence of the ravine and Pecos River and along the downstream face of the dam.

Original design (Scheme A ravine)

16. Various flows at the confluence of the ravine and Pecos River are shown in Photos 2-5. Surface flow patterns and maximum bottom velocities resulting with the maximum discharge of 430,000 cfs in the reach between the ravine and the Pecos River are shown in Photo 5b. Maximum velocities and wave wash along the dam were 21 fps and 60 ft, respectively, with a discharge of 430,000 cfs. Riprap located on the downstream face of the dam (Figure 4a), having a maximum diameter (d_{100}) of 48 in., was stable for discharges up to 225,000 cfs. Flows above 225,000 cfs induced adverse currents, surges, and stone failures on the downstream face of the dam. These severe flow conditions were primarily induced by the direction and intensity of flow entering the Pecos River and the lack of adequate energy dissipation. Wave wash height, tailwater elevation, and magnitude of velocities measured along the downstream face of the dam for the full range of discharges are provided

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a. Prior to flow

b. Subjected to 430,000 cfs for a period of 2 hr (prototype)

Figure 4. Scheme A ravine (original)

in Plates 4, 5, and 6, respectively. Figure 4b shows how the downstream riprap protection was displaced by a 2-hr duration (prototype) of a 430,000-cfs discharge.

Alternate designs - excavations

17. Portions of the ravine were excavated in an effort to reduce the flow over the lower right bench of the original Scheme A ravine (Plate 7) and dissipate some of the energy of flow entering the confluence of the ravine with the Pecos River. Initially, a cut on the left side of the ravine was made (Scheme B ravine) as shown in Plate 8. Scheme B ravine did not reduce the adverse flow conditions to an acceptable level. An additional cut was made on the right side on the edge of the bench (Scheme C ravine) as shown in Plate 9. Scheme C ravine reduced the amount of flow over the bench, but the lack of energy dissipation at the confluence of the ravine and Pecos River resulted in adverse turbulence and currents along the downstream face of the dam. Additional rock was excavated on both sides of the ravine (Scheme D ravine) as shown in Plate 10. A quasi or oblique hydraulic jump tended to form on the excavated shelf (el 4620) and satisfactory flow conditions were provided for all anticipated discharges. In an attempt to minimize rock excavation, the shelf was raised to el 4625 (Plate 11, Scheme E ravine); the quasi hydraulic jump would not form at a discharge of 430,000 cfs and flow conditions were adverse. The shelf was again excavated to el 4620 and the upstream and left portions of the shelf were filled in (Scheme F ravine) as shown in Plate 12. Performance was satisfactory for all flow conditions. The 4V-on-1H side slopes were changed to vertical cuts (Scheme G ravine, Figure 5 and Plate 13) and hydraulic performance was satisfactory and similar to the Scheme F ravine for all anticipated flow conditions. Wave wash, tailwater elevation, and current velocities near the downstream face of the dam for the Scheme G ravine are provided in Plates 4, 5, and 6. The Scheme G ravine and various hydraulic flow conditions are shown in Photos 6-9. Although the Scheme G ravine provided satisfactory hydraulic conditions (Plates 4, 5, and 6) for all anticipated flows, additional alternatives (flow deflectors) were investigated due to the
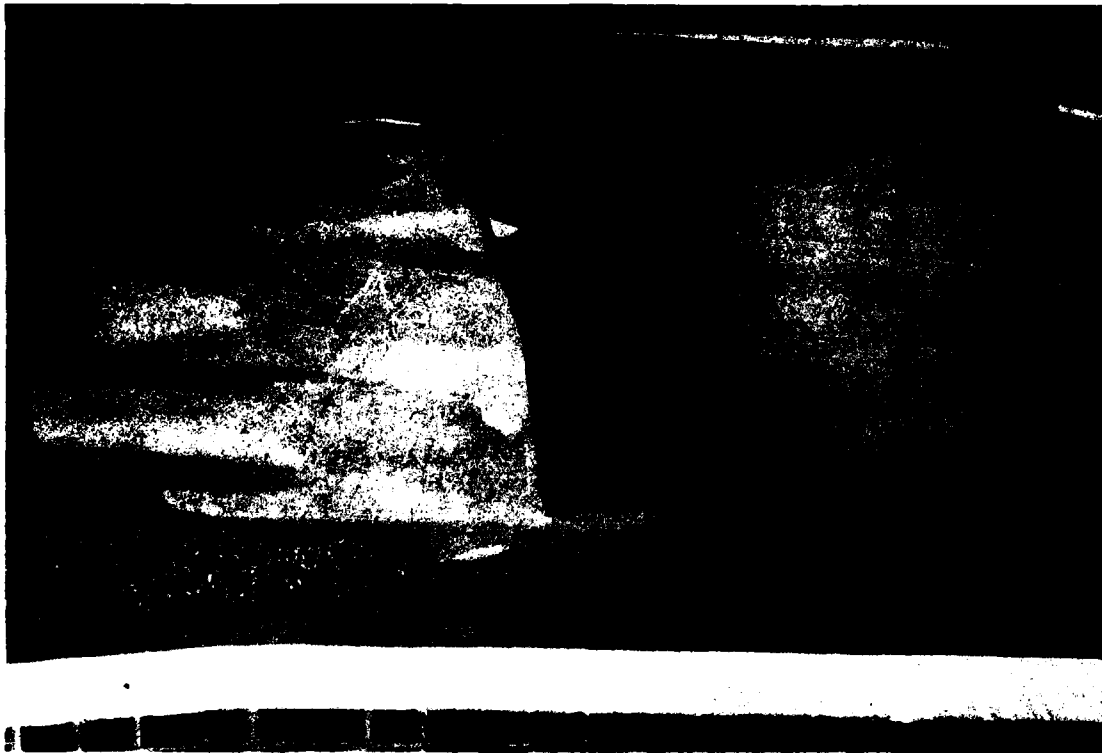
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Figure 5.   Scheme G ravine

high excavation cost required to develop the Scheme G ravine.

Alternate designs - flow deflectors

18.   Flow deflectors were investigated for the purpose of redi-
recting flow away from the dam and down the Pecos River. For dis-
charges as high as 310,000 cfs, satisfactory performance was obtained
by locating a wall or flow deflector, with a length of 385 ft and a top
elevation of 4720, on the lower right bench as shown in Figure 6. Flows
above 310,000 cfs required a top elevation of 4730 with the type 1 de-
flector. The type 1 flow deflector with a top elevation of 4730 was
effective in providing satisfactory flow conditions along the dam
(Plates 4, 5, and 6) by deflecting a portion of the flow down the Pecos
River. Flow conditions with the type 1 flow deflector are shown in
Photo 10. Reducing the wall length to 285 ft to form the type 2 flow
deflector (Figure 6, Photo 10) resulted in adverse flow conditions along
the dam embankment (Plates 4, 5, and 6).

19.   The type 3 and 4 flow deflectors (Plate 14) were overtopped
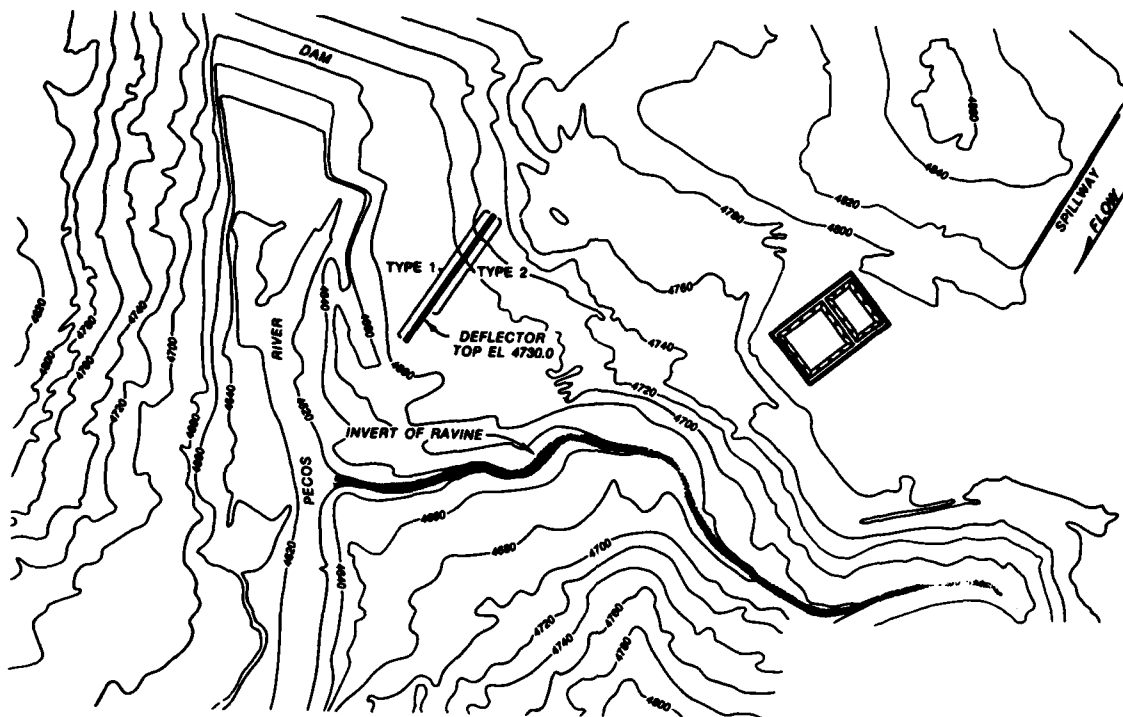
a. Type 1 and 2 flow deflectors
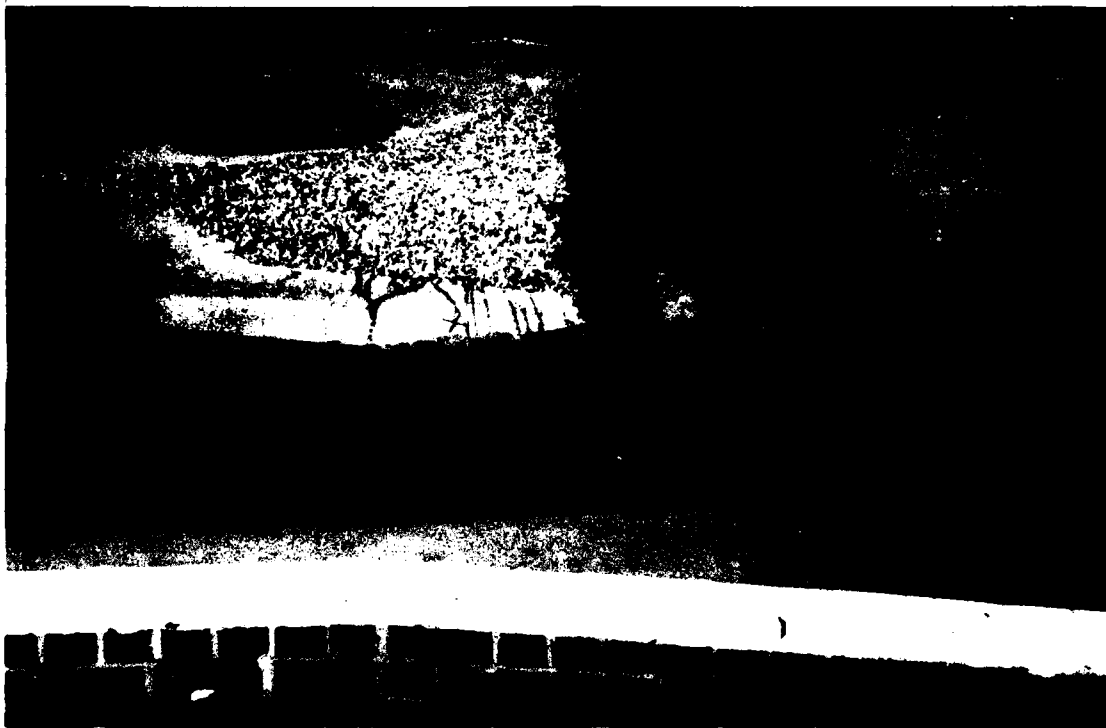

b. Type 2 flow deflector

Figure 6. Scheme A ravine (original), type 1 and 2 flow deflectors

by flow surges, and subsequent adverse flow conditions developed near the downstream face of the dam. By raising the top elevation to 4750, overtopping of the type 5 deflector (Plate 14) was reduced to a level sufficient for satisfactory hydraulic performance. Maximum velocities and wave wash along the dam were 6 fps and 25 ft, respectively, with a discharge of 430,000 cfs. The average tailwater elevation at the downstream face of the dam was 4700.

20. Due to the excessive costs of constructing a concrete wall flow deflector and the easy access to and readily available rock from the spillway excavation, it was decided to evaluate flow deflectors composed of rock. The type 6 flow deflector consisted of rock fill to el 4750 as shown in Figure 7 and Plate 15. The fill was composed of rock having an average diameter, d_{50}, of 40 in. A discharge of 100,000 cfs induced incipient displacement of rock located along the toe of the fill parallel to the ravine. A 4-hr (prototype) duration of the maximum anticipated discharge of 430,000 cfs displaced about 75 percent of the rock fill into the Pecos River. The outer perimeter of the rock fill was grouted and a discharge of 430,000 cfs is shown with a stable rock fill (Figure 8). Bottom velocities of 50 fps were measured along the side of the rock fill (Plate 15). Comparative indicators of hydraulic performance observed with the type 6 flow deflector are presented in Plates 4, 5, and 6. Test results indicated satisfactory hydraulic performance along the downstream face of the dam for all anticipated flow conditions with a stable type 6 flow deflector.

Type 7 flow deflector

21. The rock fill was modified to simulate available quarry-run rock with an average diameter, d_{50}, of 18 in. and additional quarry-run rock was placed along the downstream face of the dam. The additional rock could also be provided by excavations from the spillway. The rock berm required grout for rock stability on the side that parallels the ravine. Various flow conditions are illustrated in Photos 11-14. Bottom velocities (fps) for a discharge of 430,000 cfs are shown in Figure 9. A discharge of 430,000 cfs induced displacement of ungrouted rock along the right downstream dam embankment protection as shown in

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a.   Downstream view of ravine

b.   Downstream view of dam

Figure 7.   Type 6 flow deflector, discharge 100,000 cfs

Figure 8. Type 6 flow deflector, discharge 430,000 cfs

Photo 14b. Comparative indicators of hydraulic performance observed
with the grouted berm in the type 7 flow deflector and other alterna-
tives are presented in Plates 4, 5, and 6.

Type 8 flow deflector

22. Due to the cost of grouting the rock, alternatives to grout-
ing were investigated. The type 8 flow deflector was similar to the
type 7 flow deflector except that the rock was ungrouted and a 10-ft-
high wall was located along the toe of the rock fill as shown in Fig-
ure 10. Model tests indicated that for discharges above 100,000 cfs,
the wall was ineffective and aggravated flow conditions and failure of
the rock fill.

Type 9 flow deflector - adopted design

23. The type 9 flow deflector (Photo 15a) was identical with the
type 7 flow deflector except that the rock was ungrouted. The Albuquer-
que District requested conduct of model tests to evaluate the stability
and feasibility of the type 9 flow deflector as a sacrificial fill when
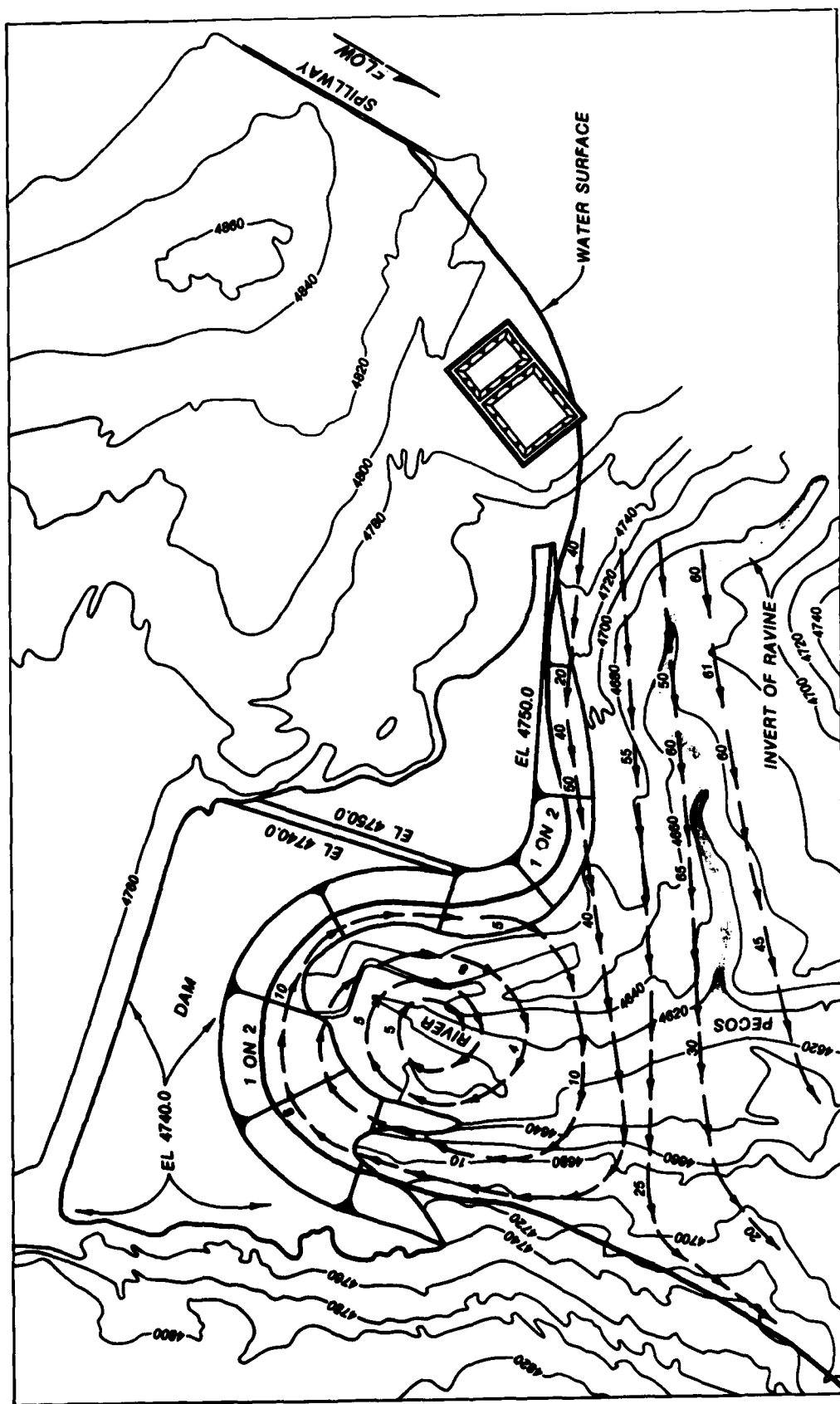
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Figure 9. Type 7 flow deflector (grouted), bottom velocities, discharge 430,000 cfs, Scheme A ravine

Figure 10. Scheme A ravine (original), type 8 flow deflector

subjected to a stepped hydrograph (Figure 11) (furnished by the Albu-
querque District). Photo 15 depicts flows that produced failure of the
rock at various stages of the hydrograph. The subphotographs pertinent
to each portion of the stepped hydrograph are keyed by circled numbers
in Figure 11 that identify the appropriate subphotographs in Photo 15.
Subphotos 15a and 15i are photographs taken before and after the
stepped hydrograph flows. Although simulation of the hydrograph re-
sulted in considerable failure to the ungrouted and sacrificial rock
fill on the berm and damage to the rock fill on the downstream face of
the dam, results of the model tests indicated that the safety of the
dam would not be jeopardized by the design flow conditions. The type 9
flow deflector was considered to be a sacrificial type of protection
and the most practical design for ensuring the safety of the dam by de-
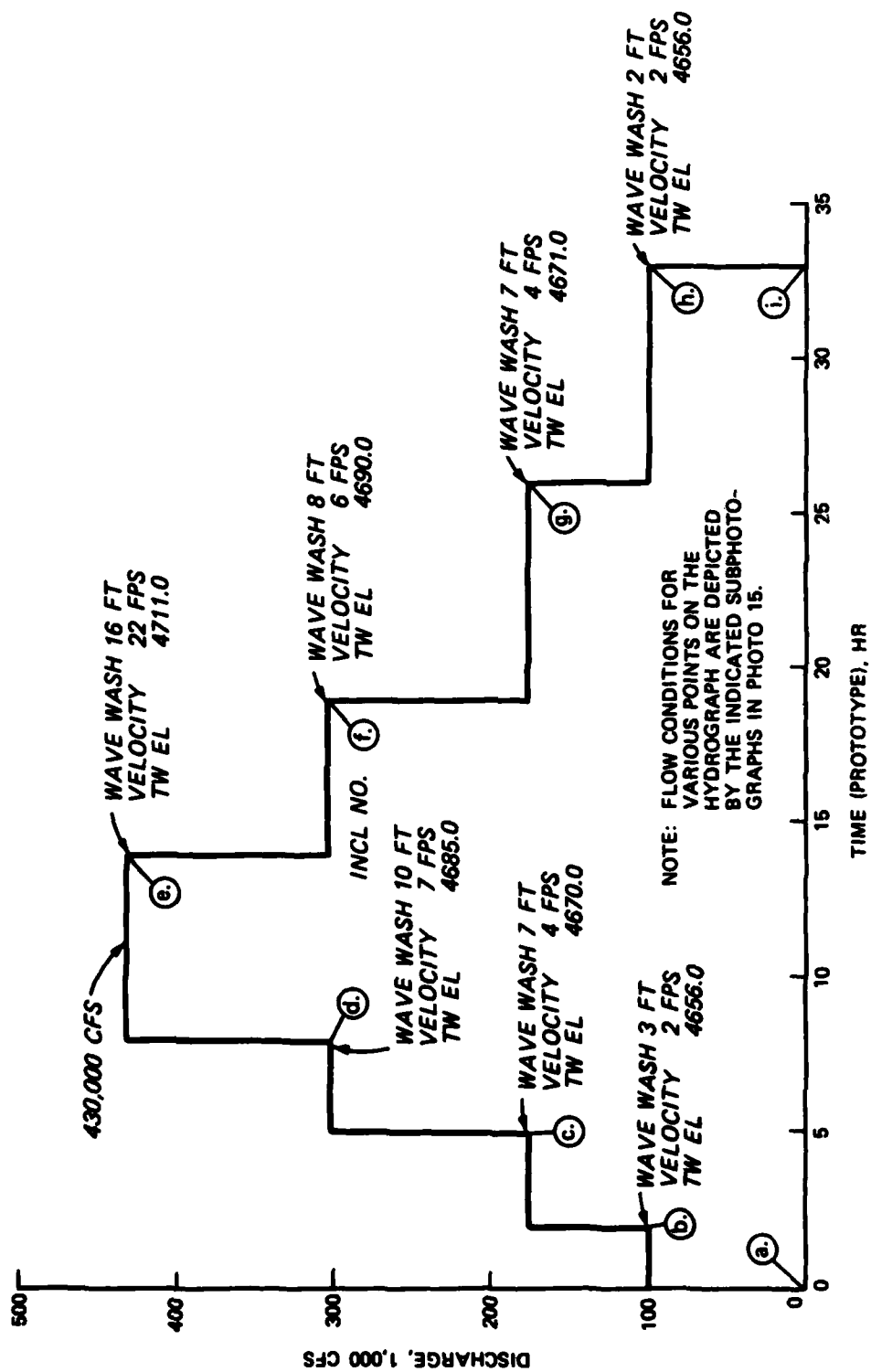flecting flow away from the dam and down the Pecos River.

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Figure 11. Scheme E ravine (original), type 9 flow deflector (ungrouted), stepped hydrograph and flow characteristics at downstream face of dam

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PART IV: CONCLUSIONS

24. Hydraulic model investigation of the Los Esteros Spillway was conducted to investigate the feasibility of increasing the capacity of the spillway from 175,000 to 430,000 cfs by increasing the crest length from 700 to 1,400 ft without endangering the safety of the dam. An intermediate crest length of 1,100 ft was also evaluated.

25. Approach and crest flows for the three crest lengths investigated were satisfactory for their respective discharges. For a given discharge, regardless of the length of crest, hydraulic characteristics were similar at the confluence of the ravine and Pecos River and along the downstream face of the dam. In the original design discharges above 225,000 cfs induced adverse currents, surges, and stone failure on the downstream face of the dam. A discharge of 430,000 cfs generated velocities and wave wash along the embankment as high as 21 fps and 60 ft, respectively.

26. Initially, portions of the model ravine were excavated to reduce the amount of return flow toward the dam and dissipate the energy of flow entering the Pecos River. Excavations forming the Scheme G ravine were effective in providing satisfactory performance for all anticipated flows. The cost of prototype excavation was considered excessive and flow deflectors were evaluated as an alternative.

27. Flow deflectors in the ravine, properly designed and constructed either of concrete or rock fill, were effective in reducing adverse flows at the dam by directing flow away from the dam and down the Pecos River. Due to excessive costs of a concrete wall and availability of rock from the spillway excavation, deflectors composed of rock were considered more practical than a concrete wall deflector.

28. The design adopted by the Albuquerque District consisted of a sacrificial ungrouted rock-fill deflector in the ravine and rock fill placed along the dam embankment. Although the rock was partially displaced by flows above 225,000 cfs, the safety of the dam was not jeopardized by discharges as high as the maximum of 430,000 cfs.

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Table 1

Basic Spillway Rating Data Obtained from Model

Crest Length ft	Discharge cfs	Pool Elevation ft NGVD
1,400	430,000	4821.0
1,400	360,000	4818.6
1,400	322,000	4816.9
1,400	294,000	4815.9
1,400	263,000	4814.6
1,400	228,000	4813.0
1,400	186,000	4811.8
1,400	132,000	4808.8
1,400	98,000	4806.4
1,100	400,000	4823.1
1,100	320,000	4820.6
1,100	280,000	4818.4
1,100	230,000	4816.0
1,100	175,000	4812.8
1,100	75,000	4806.3
700	320,000	4827.7
700	280,000	4825.8
700	230,000	4822.3
700	175,000	4818.4
700	125,000	4814.0
700	75,000	4809.3

a. Discharge 175,000 cfs

b. Discharge 300,000 cfs

c. Discharge 430,000 cfs

Photo 1. Spillway flows, 1,400-ft-long crest

a. Downstream view of ravine

b. Downstream view of dam

Photo 2. Scheme A ravine (original), discharge 100,000 cfs
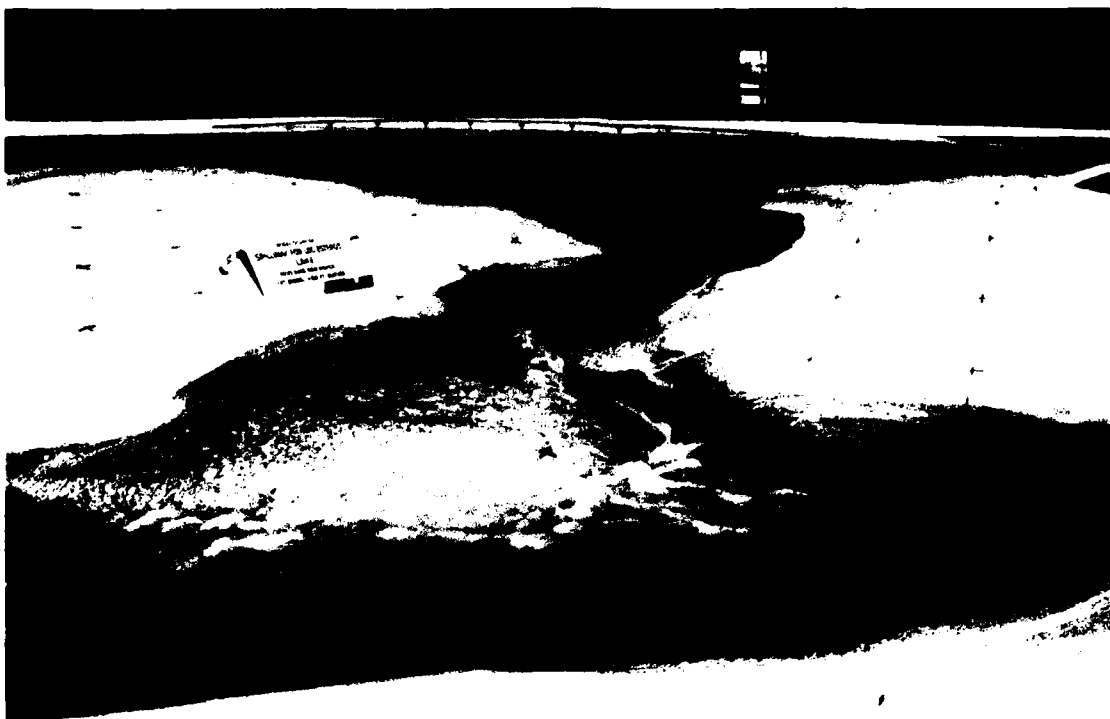
a. Downstream view of ravine
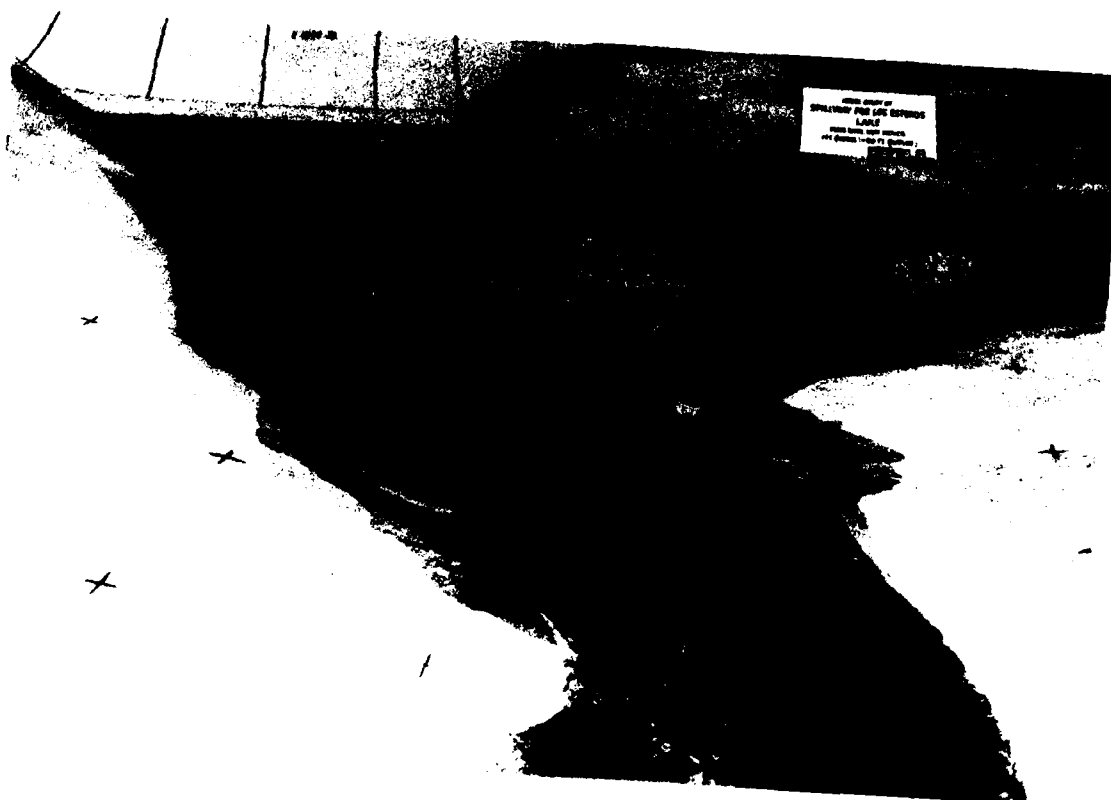
b. Downstream view of dam

Photo 3. Scheme A ravine (original), discharge 175,000 cfs
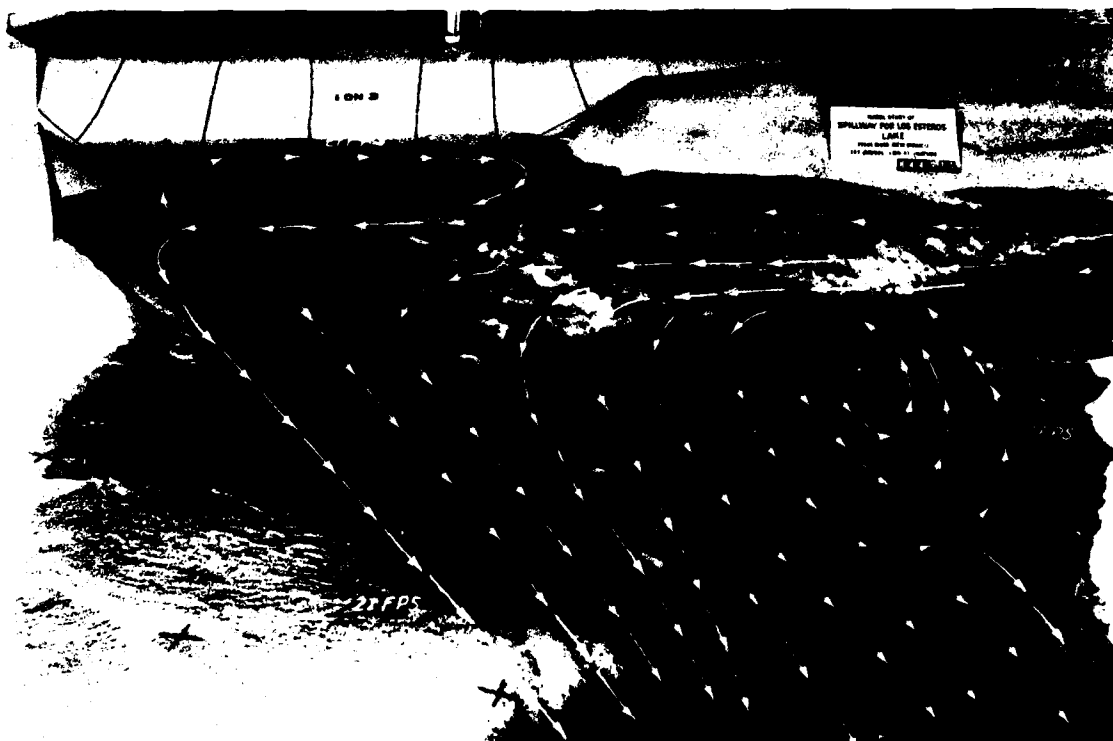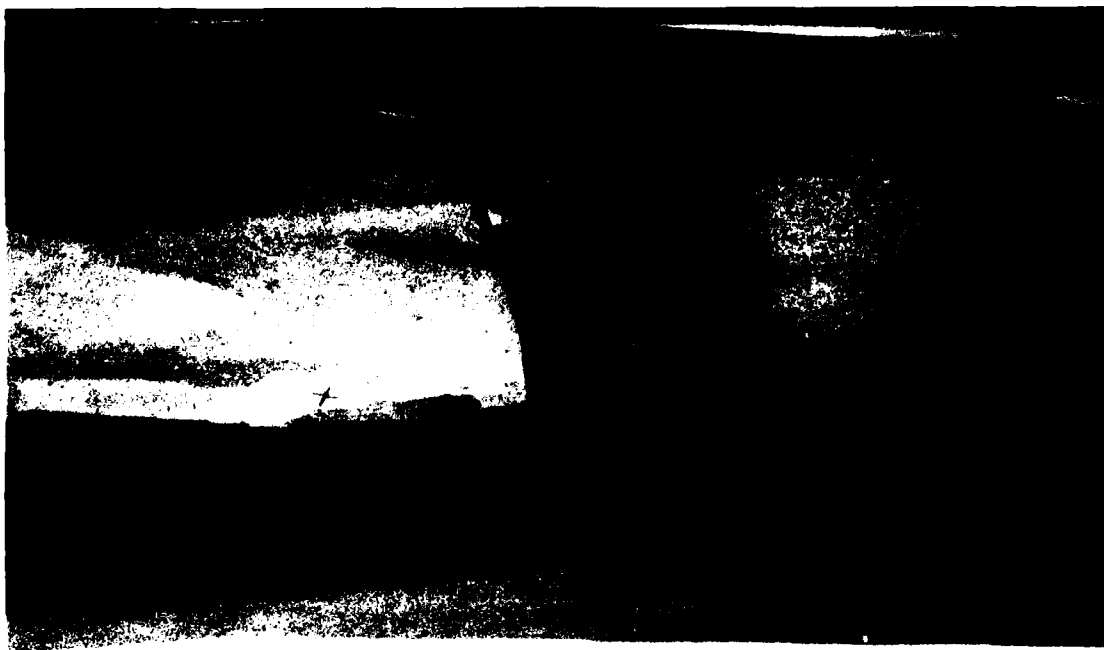
a. Downstream view of ravine

b. Downstream view of dam

Photo 4. Scheme A ravine (original), discharge 300,000 cfs

a. Downstream view of ravine

b. Downstream view of dam

Photo 5. Scheme A ravine (original), discharge 430,000 cfs

a. Downstream view of ravine

b. Downstream view of dam

Photo 6. Scheme G ravine, discharge 100,000 cfs

a. Downstream view of ravine

b. Downstream view of dam
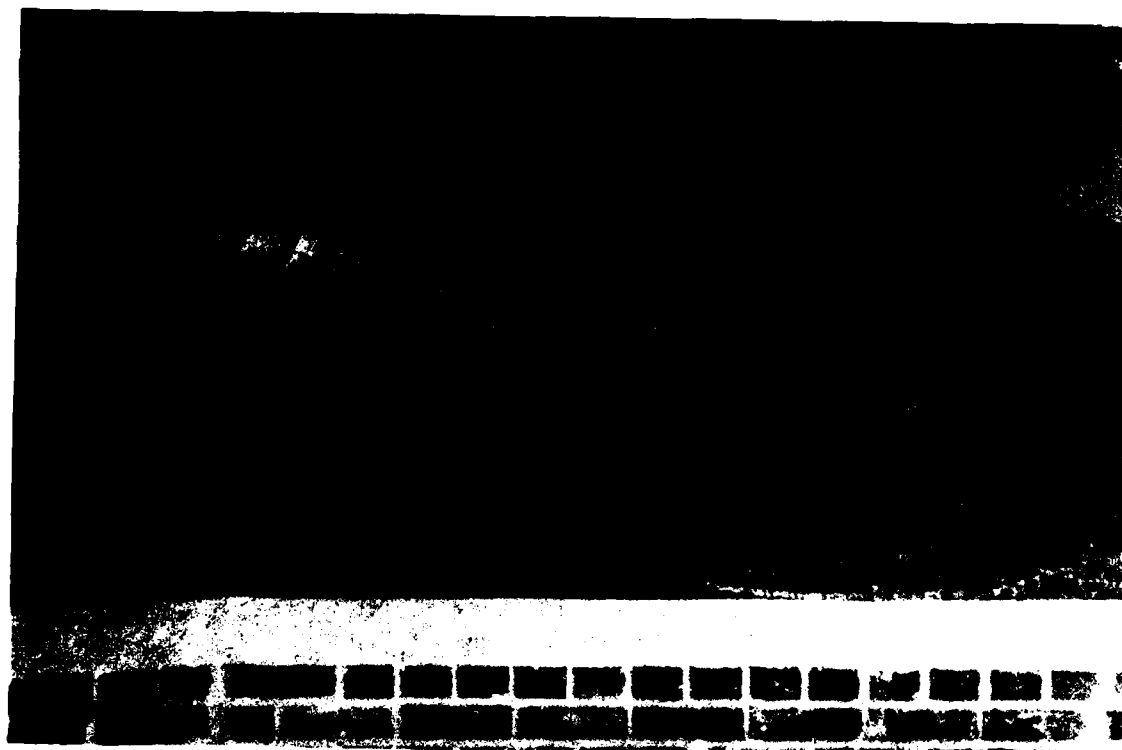
Photo 7. Scheme G ravine, discharge 175,000 cfs

a. Downstream view of ravine

b. Downstream view of dam

Photo 8. Scheme G ravine, discharge 300,000 cfs

a. Downstream view of ravine

b. Downstream view of dam

Photo 9. Scheme G ravine, discharge 430,000 cfs

a. Type 1 flow deflector

b. Type 2 flow deflector

Photo 10. Scheme A ravine (original), type 1 and 2
flow deflectors; discharge 430,000 cfs

a. Downstream view of ravine

b. Downstream view of dam

Photo 11. Type 7 flow deflector (grouted), discharge 100,000 cfs
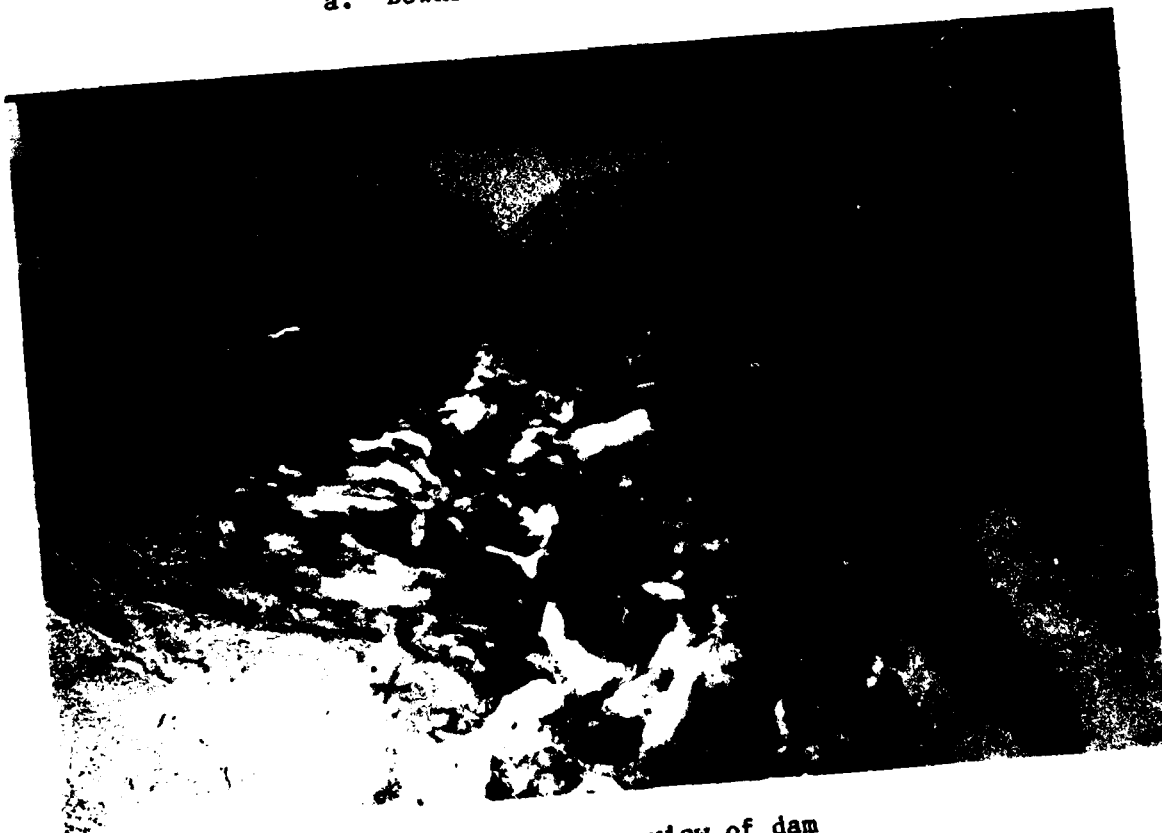
a. Downstream view of ravine

b. Downstream view of dam

Photo 12. Type 7 flow deflector, discharge 175,000 cfs

a. Downstream view of ravine

b. Downstream view of dam

Photo 13. Type 7 flow deflector, discharge 300,000 cfs

a. Downstream view of ravine

b. Downstream view of dam
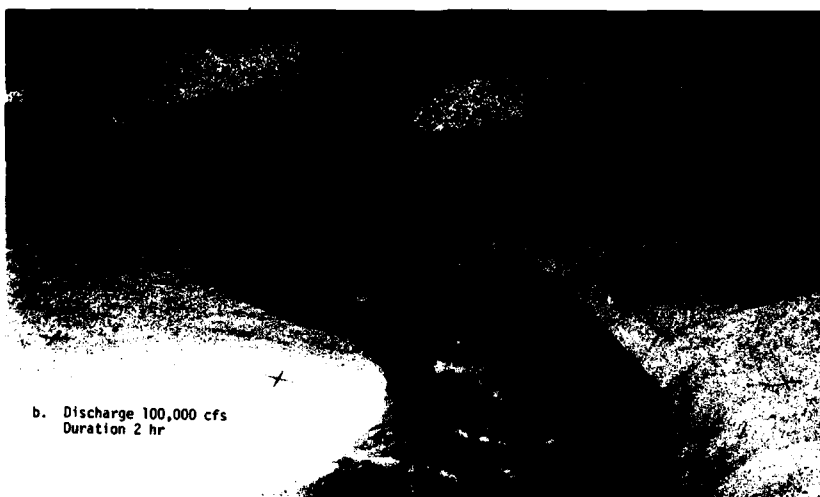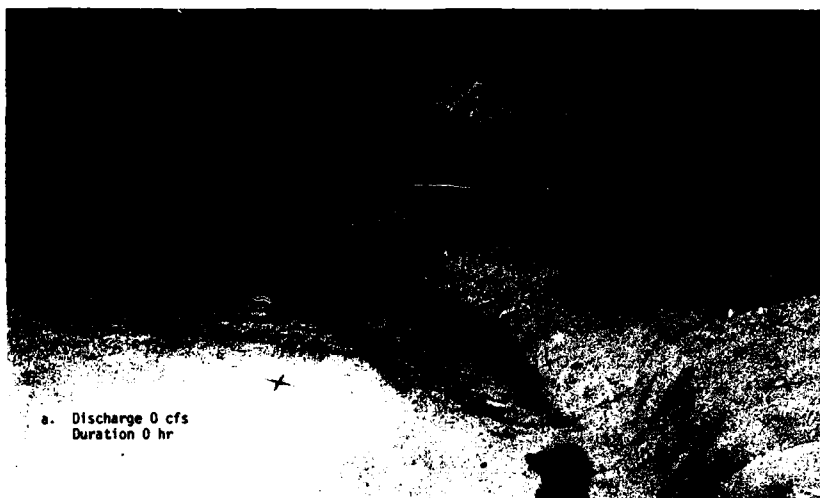
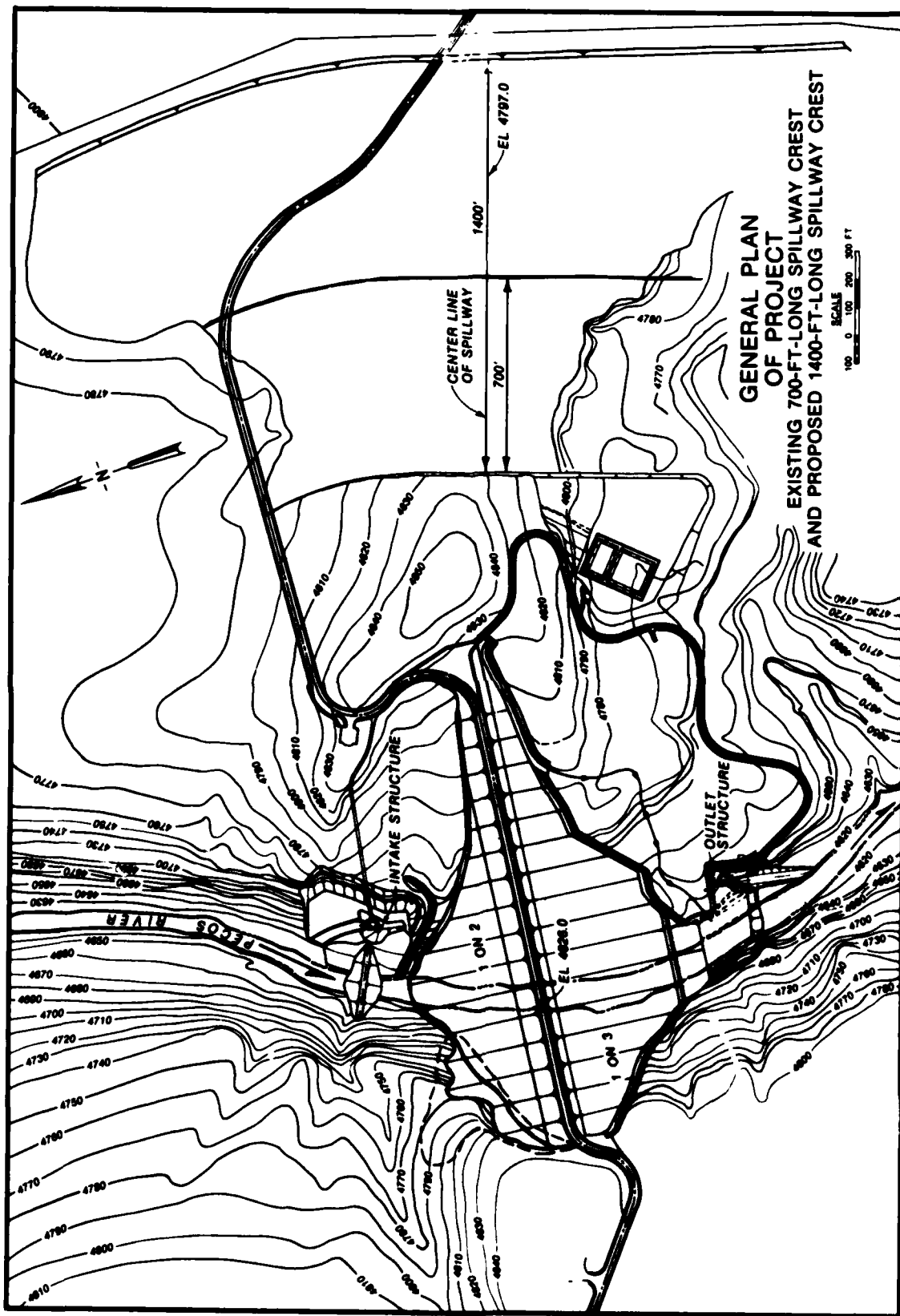Photo 14. Type 7 flow deflector, discharge 430,000 cfs

a. Discharge 0 cfs
Duration 0 hr

b. Discharge 100,000 cfs
Duration 2 hr

c. Discharge 175,000 cfs
Duration 5 hr

Photo 15.   Scheme A ravine (original), type 9 flow deflector
(Sheet 1 of 3)

d. Discharge 300,000 cfs
   Duration 8 hr

e. Discharge 430,000 cfs
   Duration 14 hr

f. Discharge 300,000 cfs
   Duration 19 hr

Photo 15. (Sheet 2 of 3)

g. Discharge 175,000 cfs
Duration 26 hr

h. Discharge 100,000 cfs
Duration 33 hr

i. Discharge 0 cfs
Duration 33 hr

Photo 15.   (Sheet 3 of 3)

GENERAL PLAN
OF PROJECT

EXISTING 700-FT-LONG SPILLWAY CREST
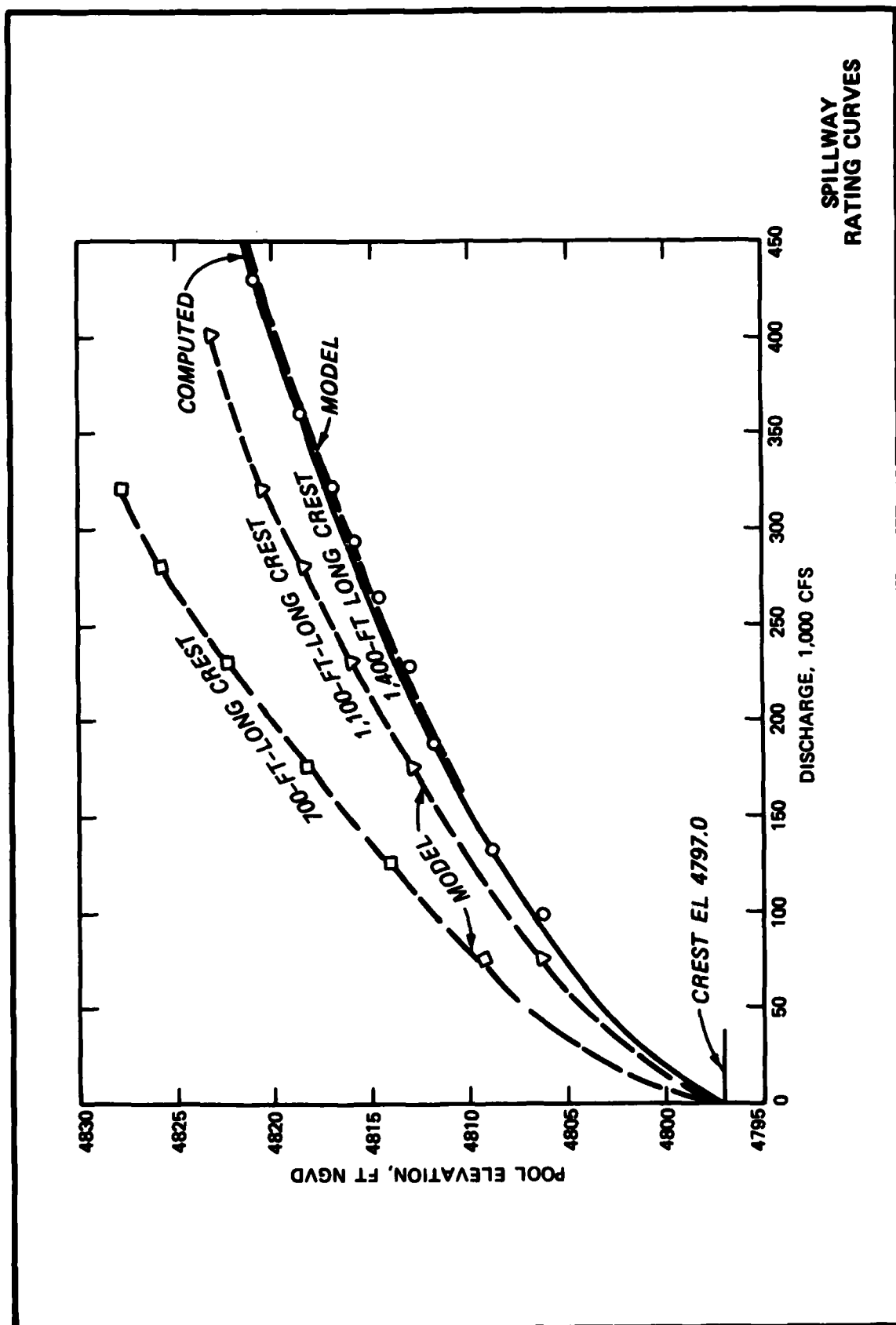AND PROPOSED 1400-FT-LONG SPILLWAY CREST

SCALE
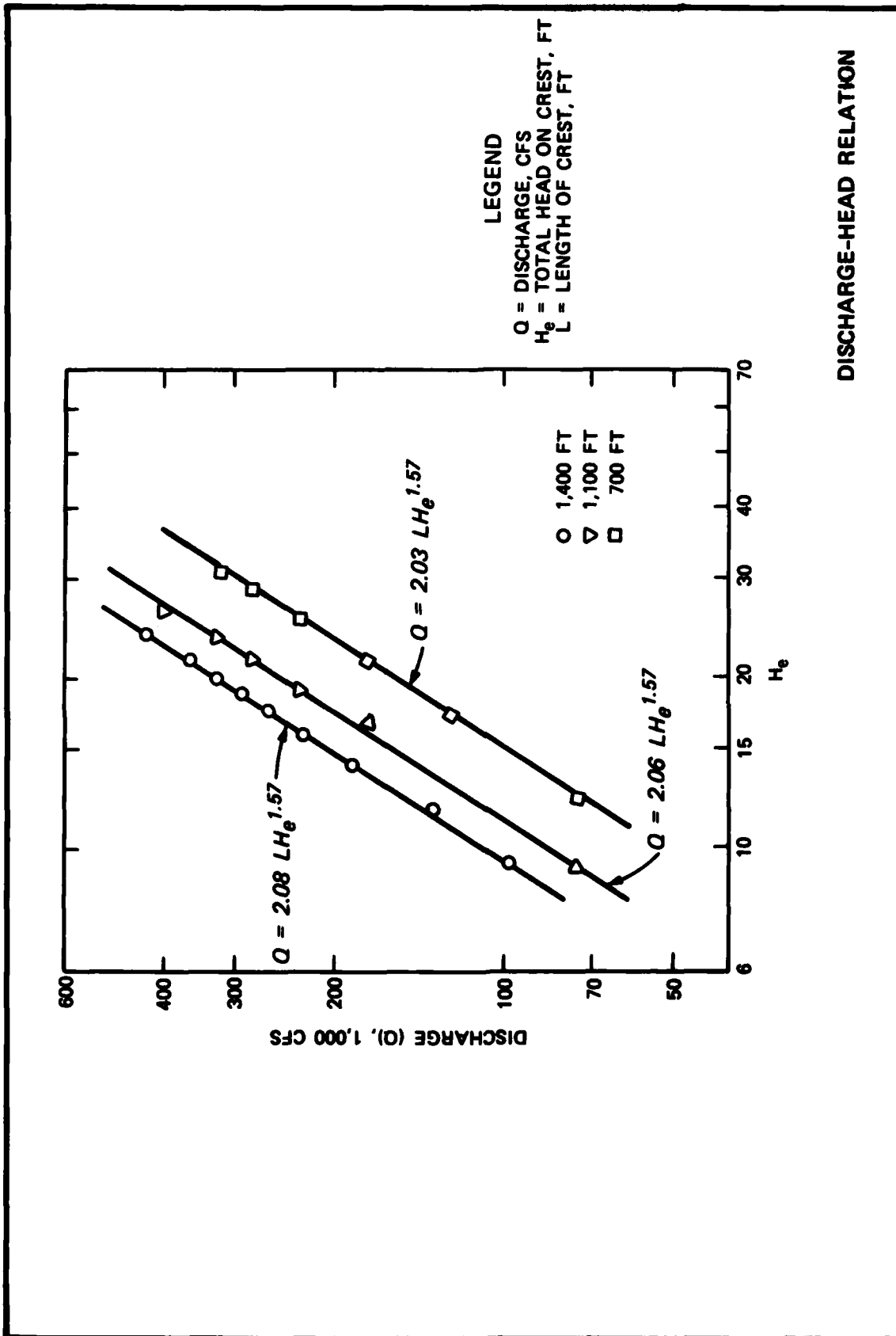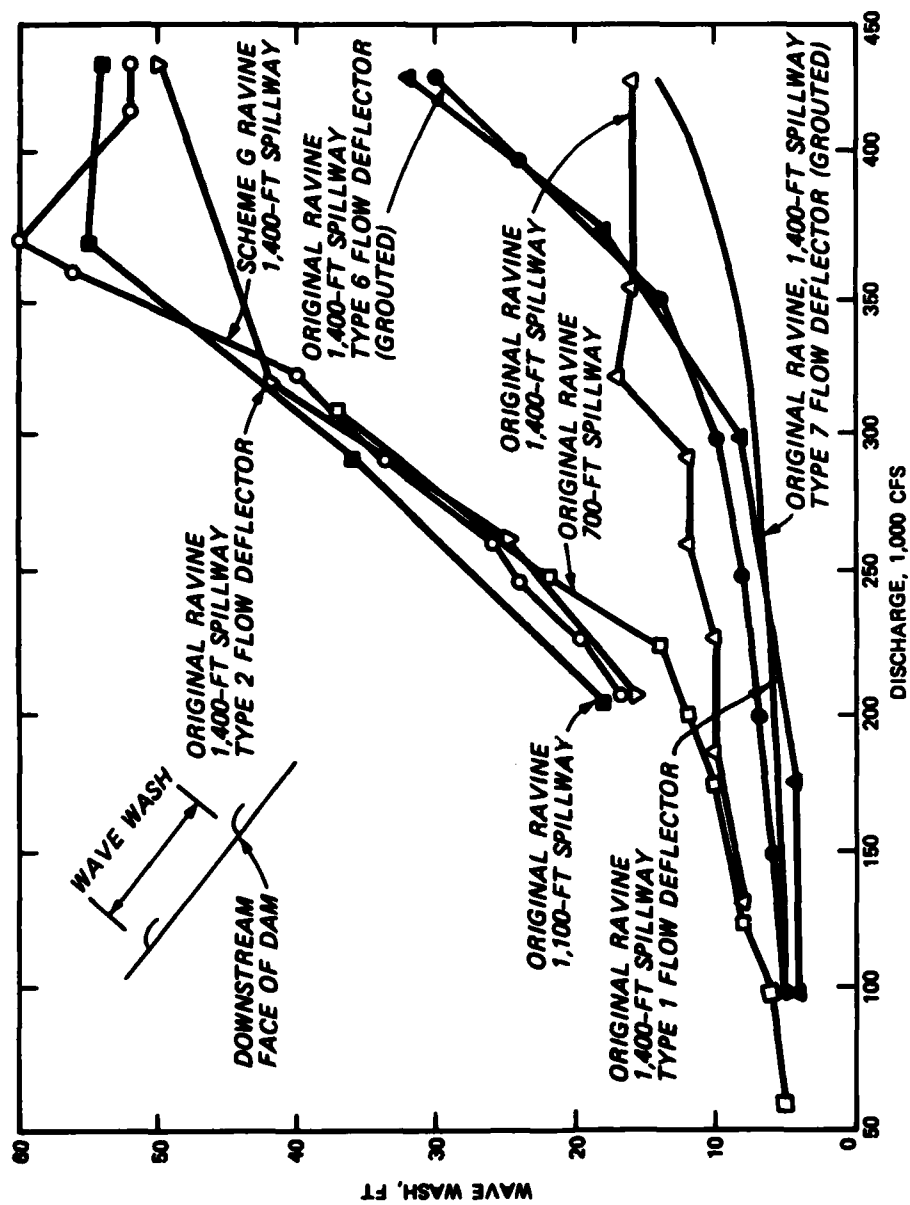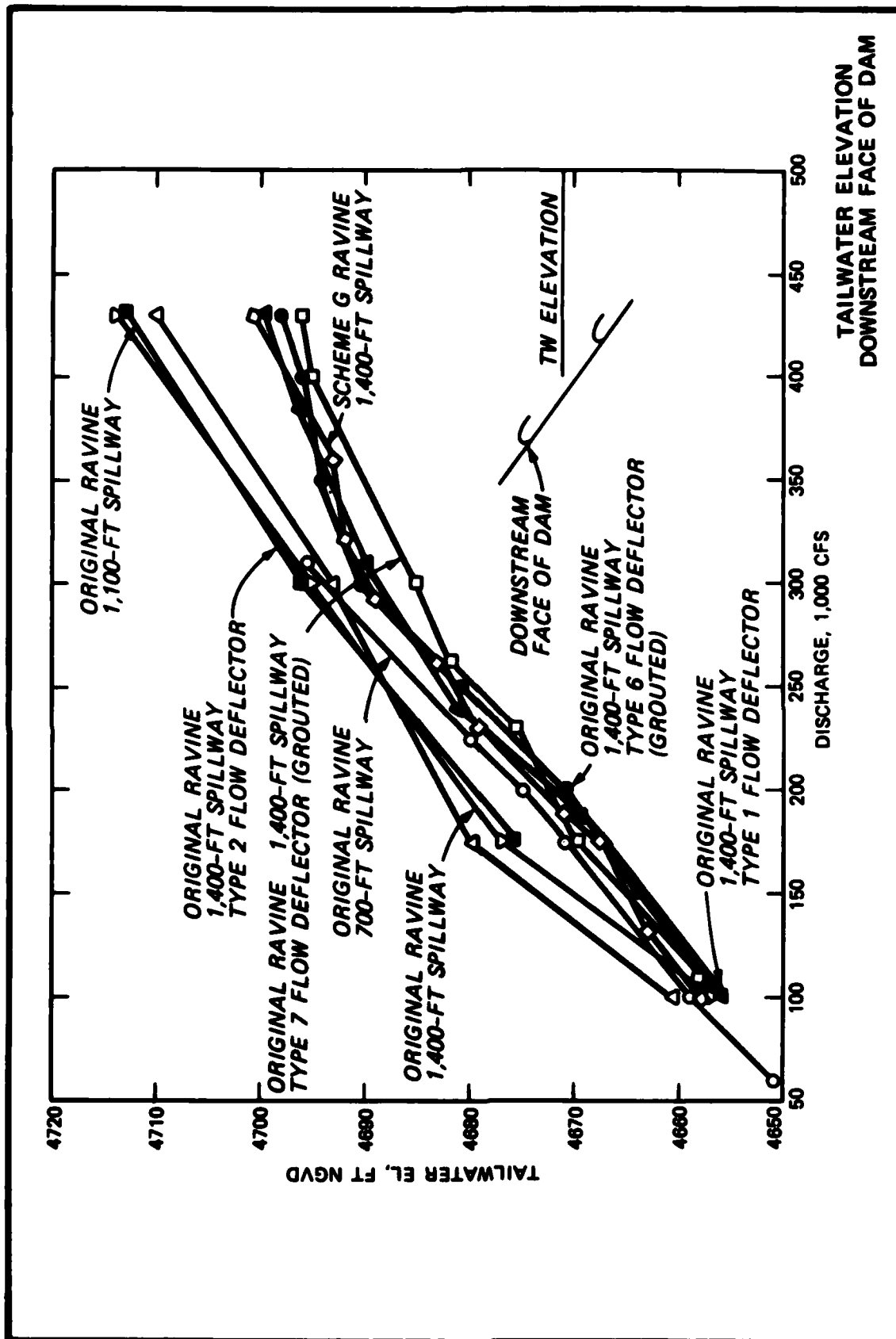100 0 100 200 300 FT

PLATE 1

SPILLWAY
RATING CURVES

PLATE 2

LEGEND

Q = DISCHARGE, CFS
H_e = TOTAL HEAD ON CREST, FT
L = LENGTH OF CREST, FT

DISCHARGE-HEAD RELATION

PLATE 3

WAVE WASH
DOWNSTREAM FACE OF DAM

PLATE 4

ORIGINAL RAVINE
1,100-FT SPILLWAY

ORIGINAL RAVINE
1,400-FT SPILLWAY
TYPE 2 FLOW DEFLECTOR

ORIGINAL RAVINE   1,400-FT SPILLWAY
TYPE 7 FLOW DEFLECTOR (GROUTED)

ORIGINAL RAVINE
700-FT SPILLWAY

ORIGINAL RAVINE
1,400-FT SPILLWAY

SCHEME G RAVINE
1,400-FT SPILLWAY

DOWNSTREAM
FACE OF DAM

TW ELEVATION

ORIGINAL RAVINE
1,400-FT SPILLWAY
TYPE 6 FLOW DEFLECTOR
(GROUTED)

ORIGINAL RAVINE
1,400-FT SPILLWAY
TYPE 1 FLOW DEFLECTOR

TAILWATER ELEVATION
DOWNSTREAM FACE OF DAM

DISCHARGE, 1,000 CFS

TAILWATER EL, FT NGVD

PLATE 5

LEGEND

ORIGINAL RAVINE, 1,400-FT SPILLWAY
TYPE 7 FLOW DEFLECTOR (GROUTED)

ORIGINAL RAVINE, 1,400-FT SPILLWAY

ORIGINAL RAVINE, 1,100-FT SPILLWAY

ORIGINAL RAVINE, 700-FT SPILLWAY

SCHEME G RAVINE, 1,400-FT SPILLWAY

ORIGINAL RAVINE, 1,400-FT SPILLWAY
TYPE 1 FLOW DEFLECTOR

ORIGINAL RAVINE, 1,400-FT SPILLWAY
TYPE 2 FLOW DEFLECTOR

ORIGINAL RAVINE, 1,400-FT SPILLWAY
TYPE 6 FLOW DEFLECTOR (GROUTED)
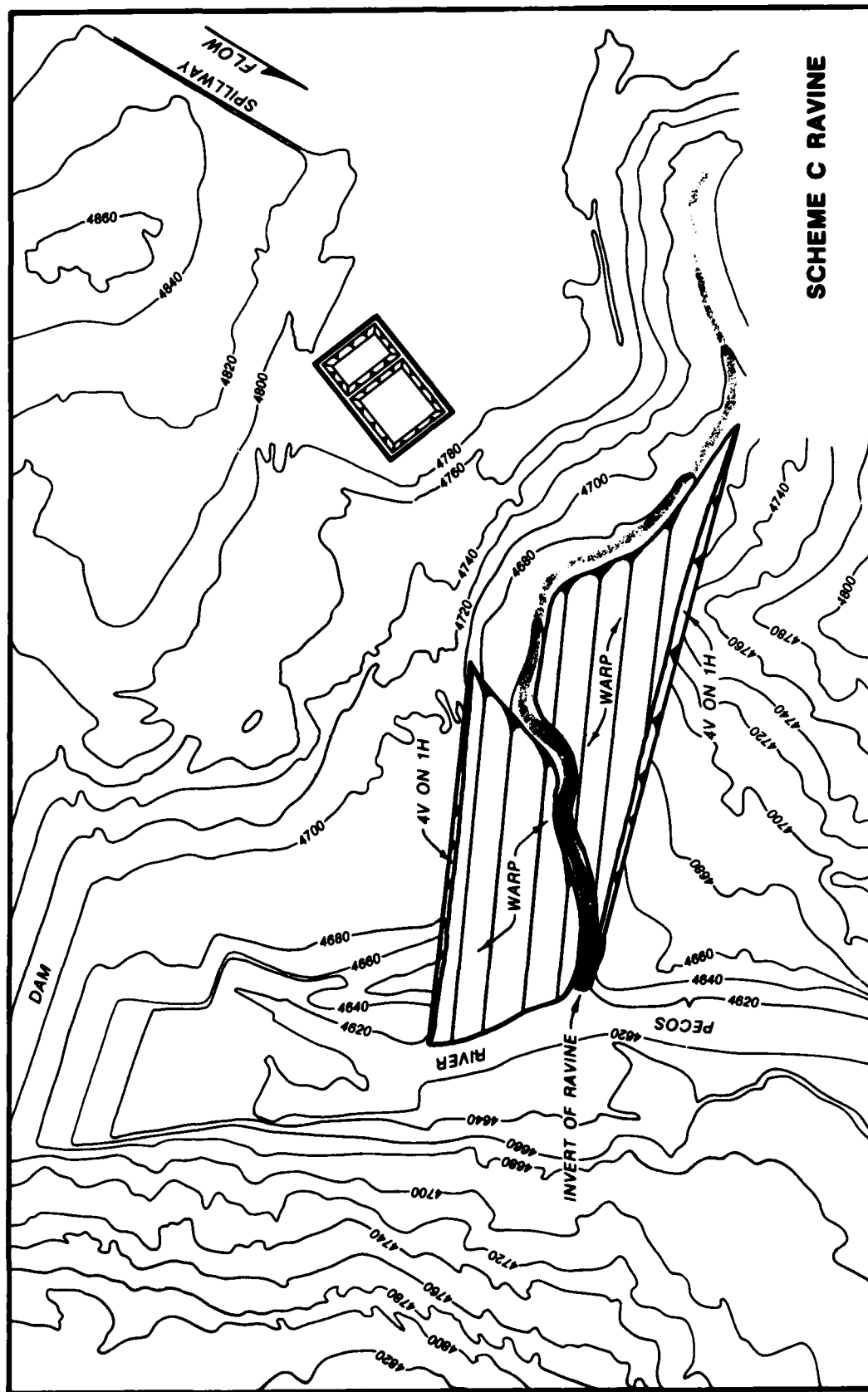
VELOCITIES
DOWNSTREAM FACE OF DAM

PLATE 6
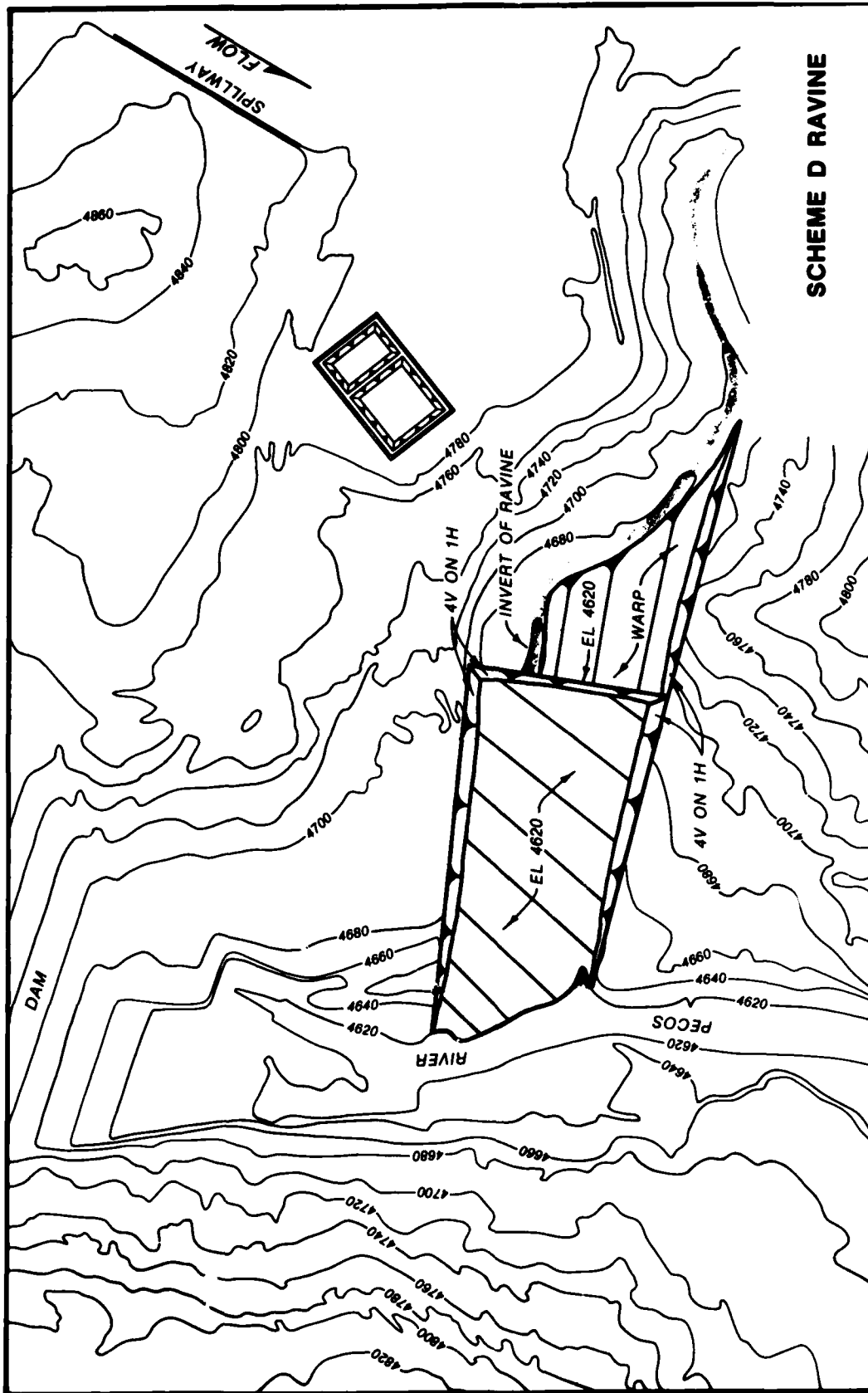
SCHEME A RAVINE
(ORIGINAL DESIGN)
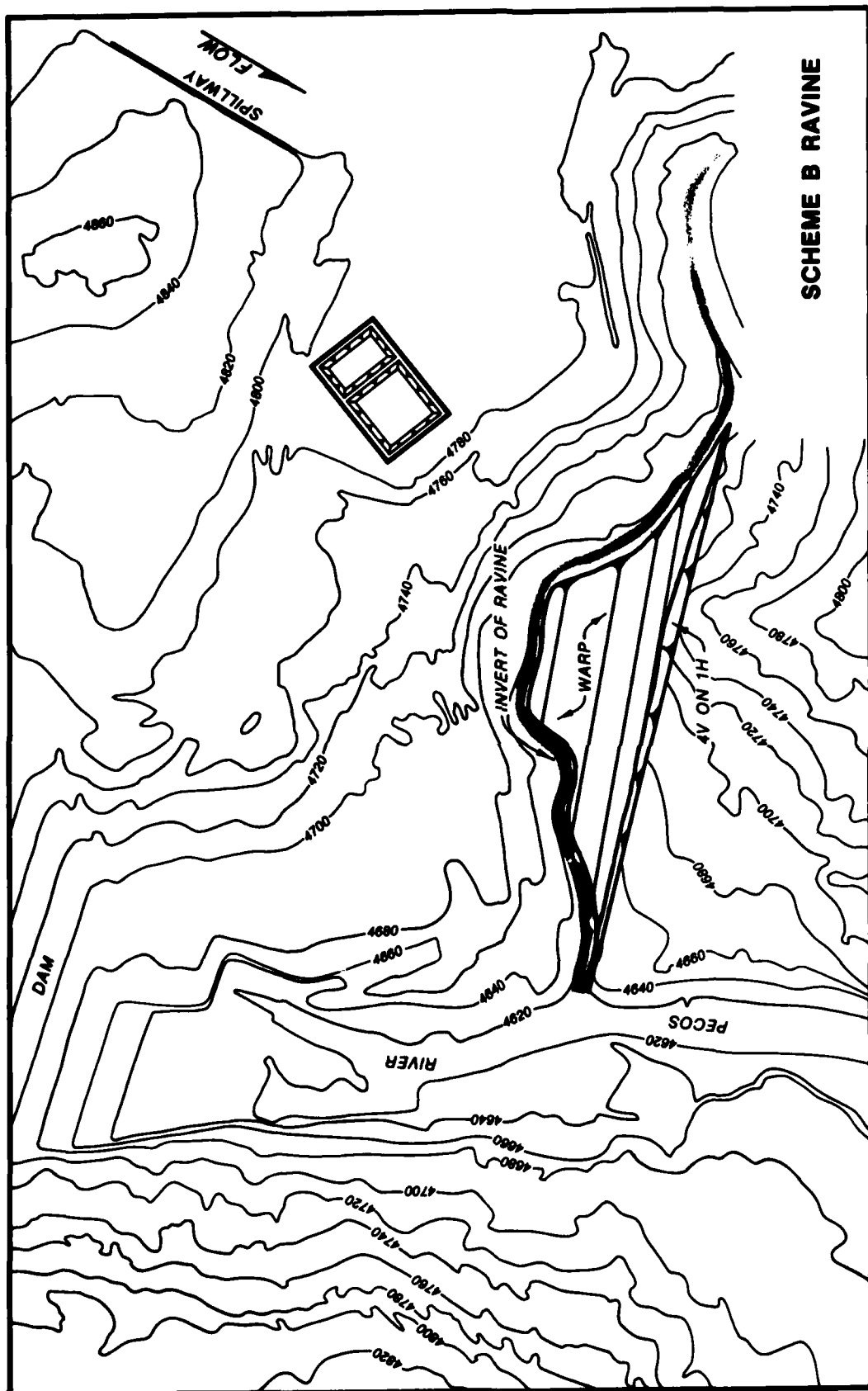
PLATE 7

SCHEME B RAVINE

PLATE 8

SCHEME C RAVINE

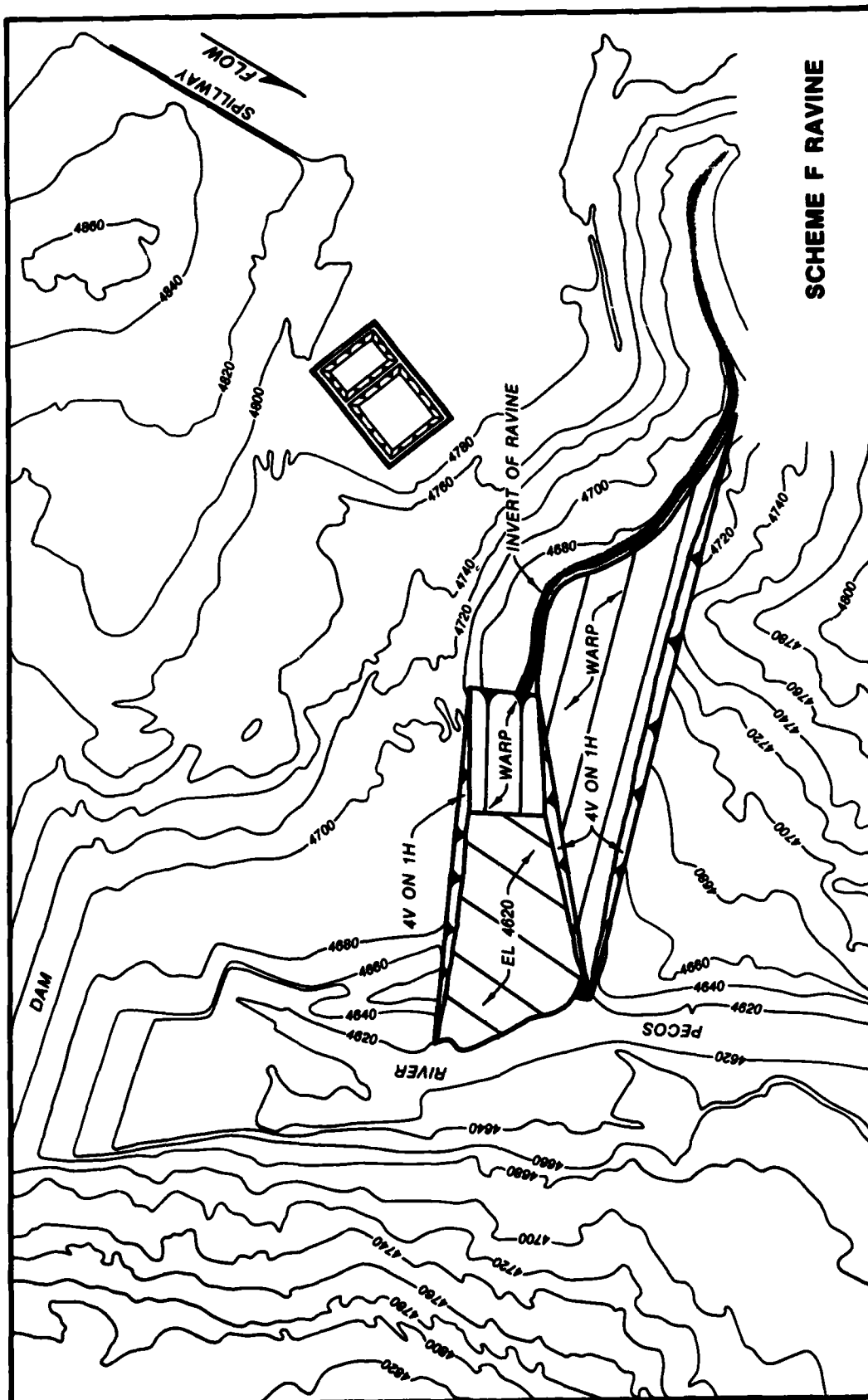PLATE 9

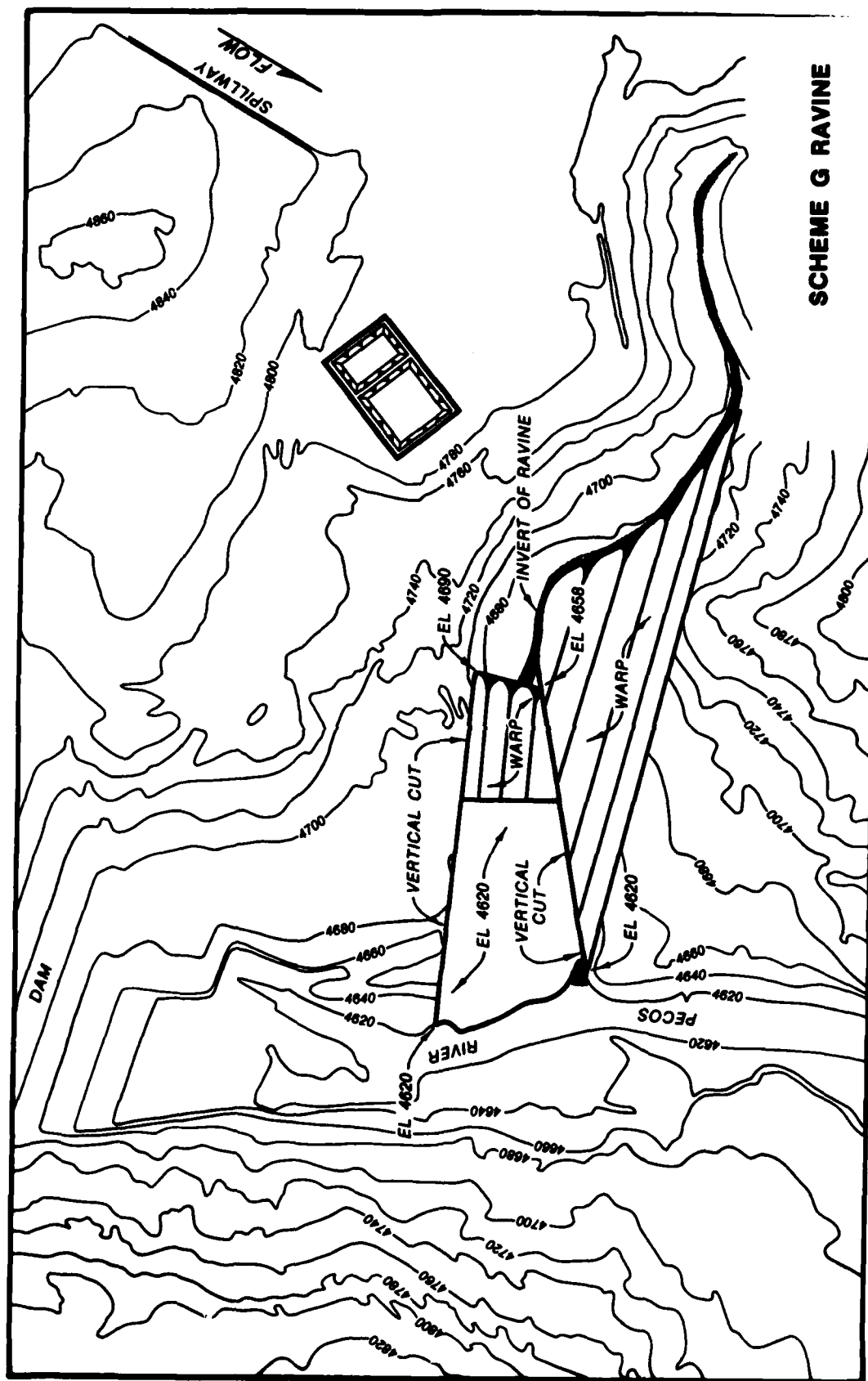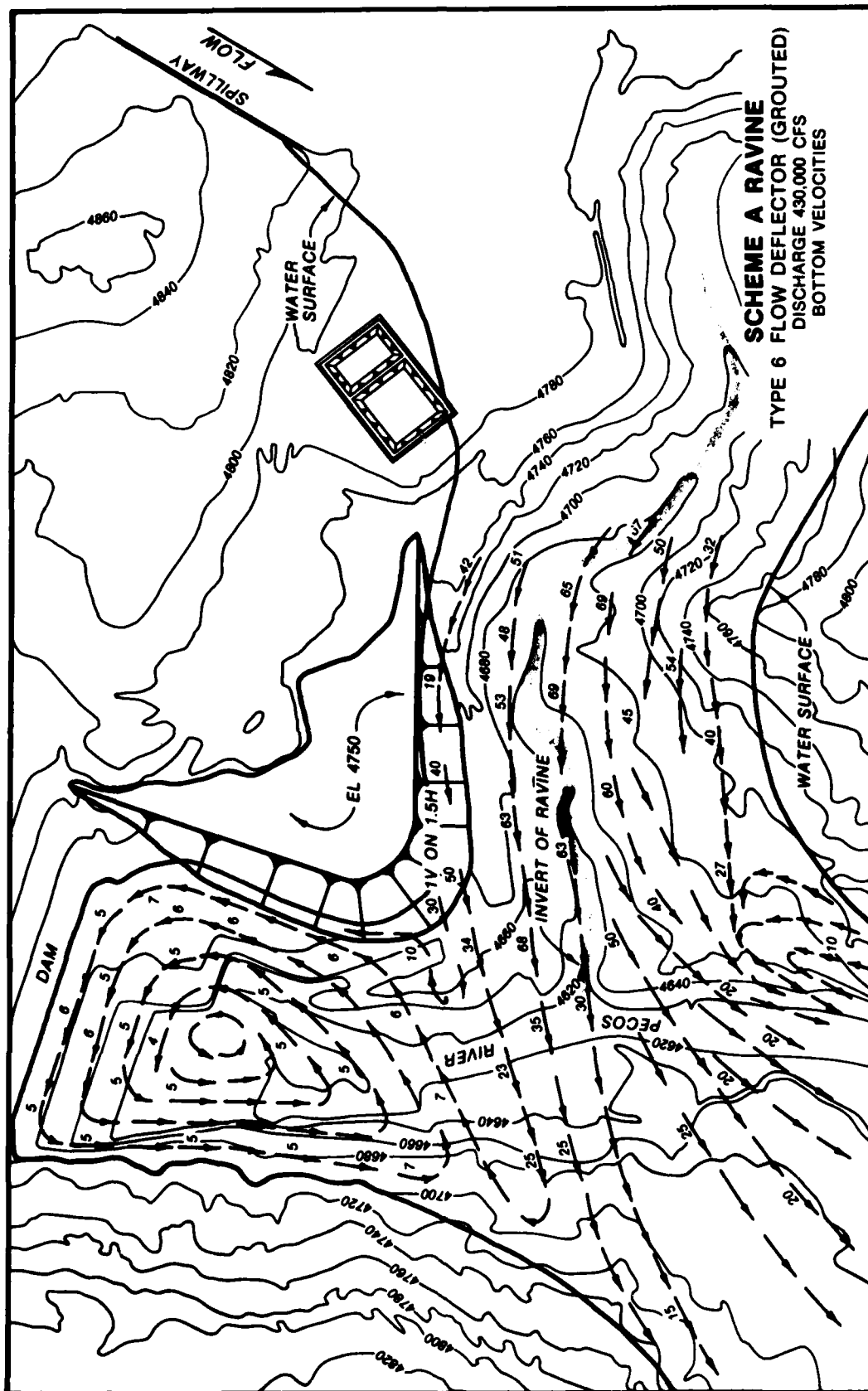SCHEME D RAVINE

PLATE 10
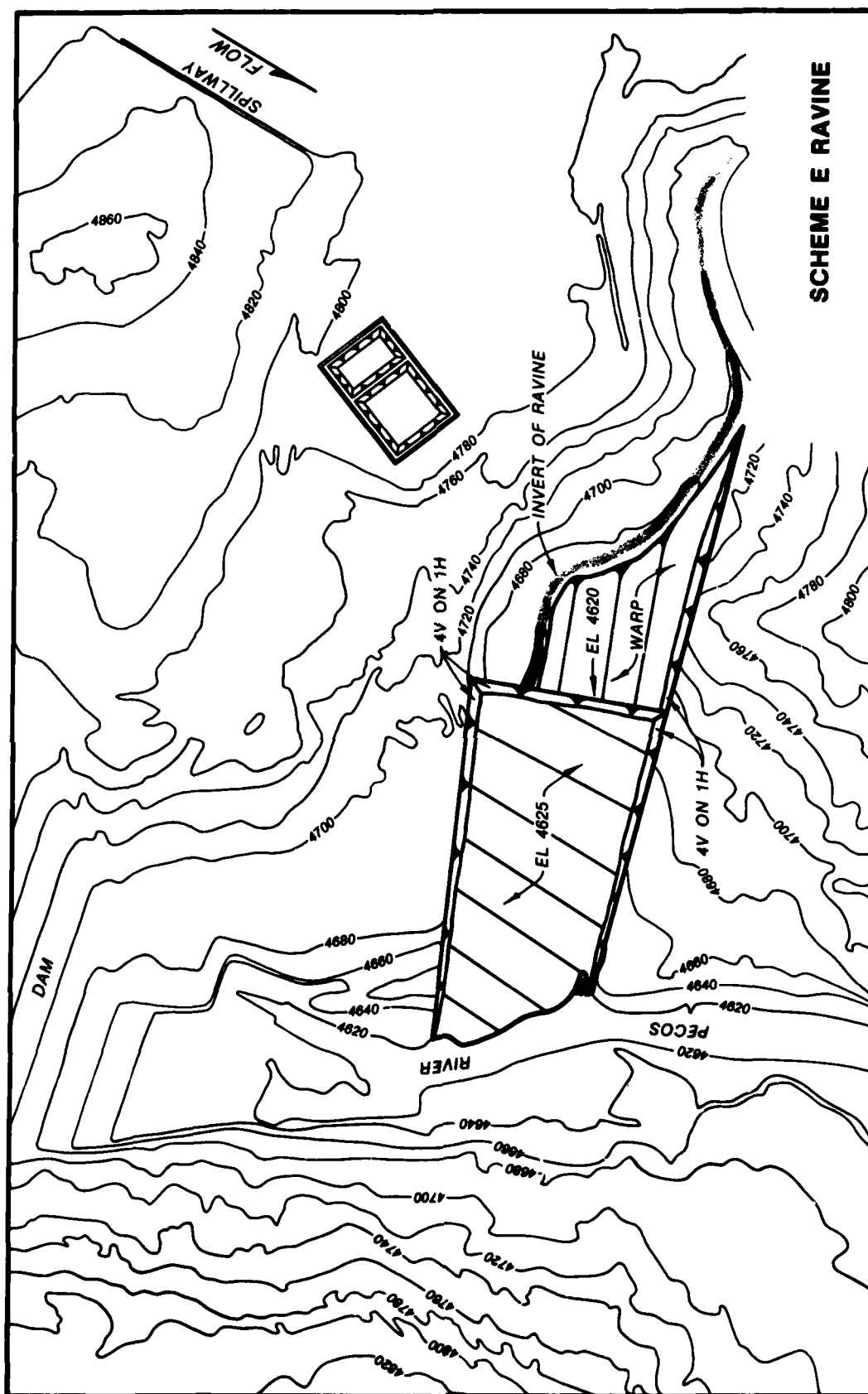
SCHEME E RAVINE

PLATE 11

SCHEME F RAVINE

PLATE 12

SCHEME G RAVINE

PLATE 13

SPILLWAY FLOW

4860
4840
4820
4800
4760

SCHEME A RAVINE (ORIGINAL)
TYPE 3, 4 AND 5 FLOW DEFLECTORS

4740
4720
4700

INVERT OF RAVINE

4780
4800
4780
4760
4740
4720
4700
4680

TOP

1V ON 1.5H

4740
4720
4700
4680
4660

4680
4660
4640
4620

PECOS

4620

DAM

RIVER

TYPE 3, TOP EL 4730
TYPE 4, TOP EL 4740
TYPE 5, TOP EL 4750

4640
4660
4680
4700
4720
4740
4760
4780
4800
4820

PLATE 14

SCHEME A RAVINE

TYPE 6 FLOW DEFLECTOR (GROUTED)
DISCHARGE 430,000 CFS
BOTTOM VELOCITIES

PLATE 15

Fletcher, Bobby P.
  Los Esteros Spillway, Pecos River, New Mexico :
Hydraulic Model Investigation / by Bobby P. Fletcher
(Hydraulics Laboratory, U.S. Army Engineer Waterways
Experiment Station). -- Vicksburg, Miss. : The Station ;
Springfield, Va. ; available from NTIS, 1982.
  23, [18] p., 15 p. of plates ; ill. ; 27 cm. --
(Technical report ; HL-82-24)
  Cover title.
  "October 1982."
  Final report.
  "Prepared for U.S. Army Engineer District, Albuquerque."

  1. Hydraulic models. 2. Los Esteros Spillway (N.M.)
3. Pecos River. 4. Spillways. I. United States.
Army. Corps of Engineers. Albuquerque District.
II. U.S. Army Engineer Waterways Experiment Station.
Hydraulics Laboratory. III. Title IV. Series:

Fletcher, Bobby P.
  Los Esteros Spillway, Pecos River, New Mexico : ... 1982.
                                                 (Card 2)

Technical report (U.S. Army Engineer Waterways Experiment
Station) ; HL-82-24.
TA7.W34 no.HL-82-24